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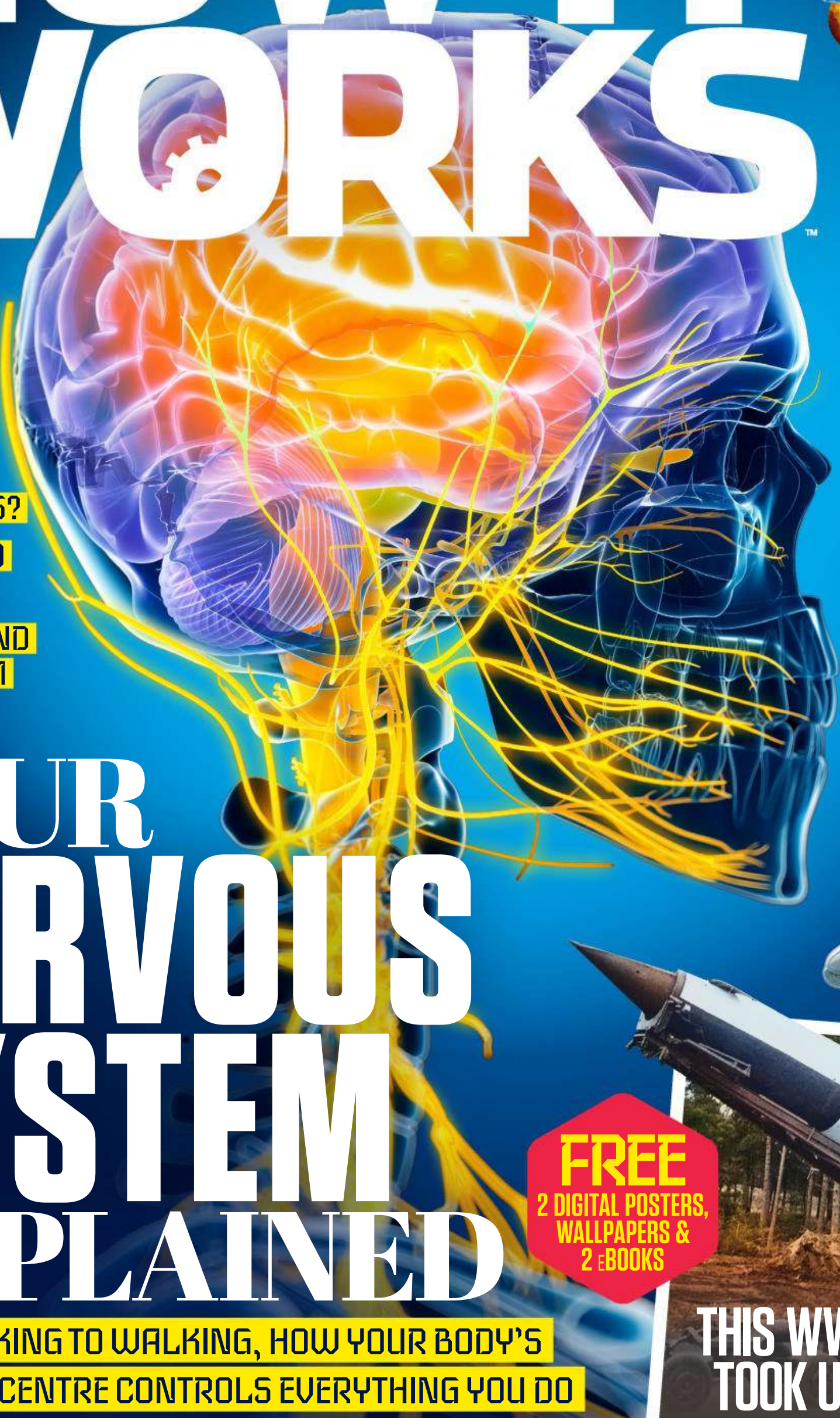

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YOUR NERVOUS SYSTEM EXPLAINED

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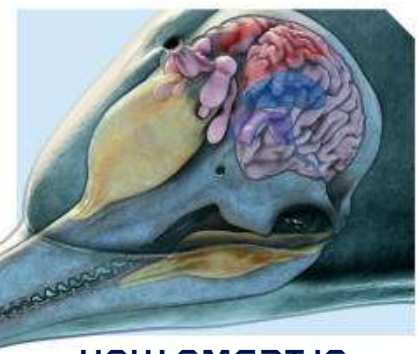

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FUTURE
ISSUE 163

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WELCOME

Issue 163

"The nervous system gives us the power of thought and action"

Your nervous system explained
PAGE 26

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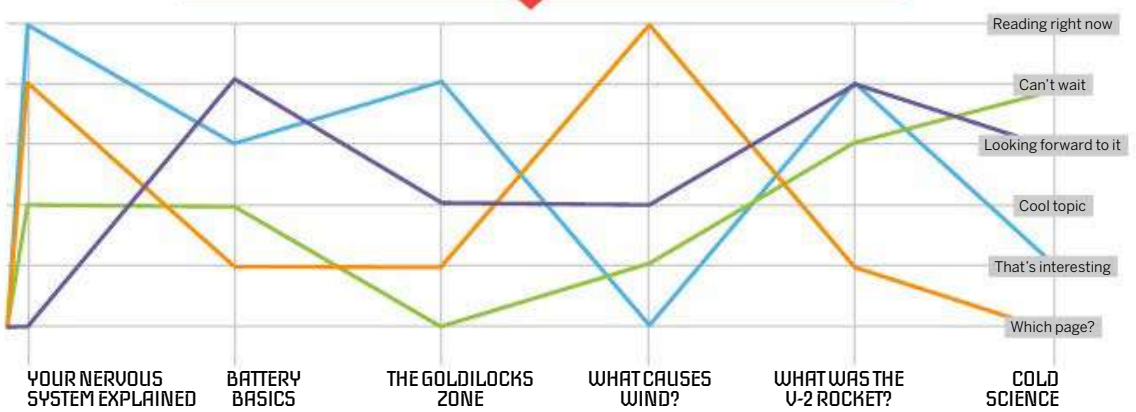
It's incredible how much of an active role our nervous system has in every part of our existence without us realising it. It even plays a part in our conversations: next time someone accuses you of 'getting on their nerves', you can tell them that stress and anxiety are thought to cause nerves to fire more often, which may result in a tingling and burning sensation that feels similar to nerve damage, but this can't actually damage the nerves. That's certain to make them feel better about you annoying them! On page 26, discover how the nervous system governs everything from thinking to walking, how it can be damaged and how medicine can manage the most common nervous diseases. Enjoy!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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How this network of cells coordinates everything you do, from a single thought to running a marathon

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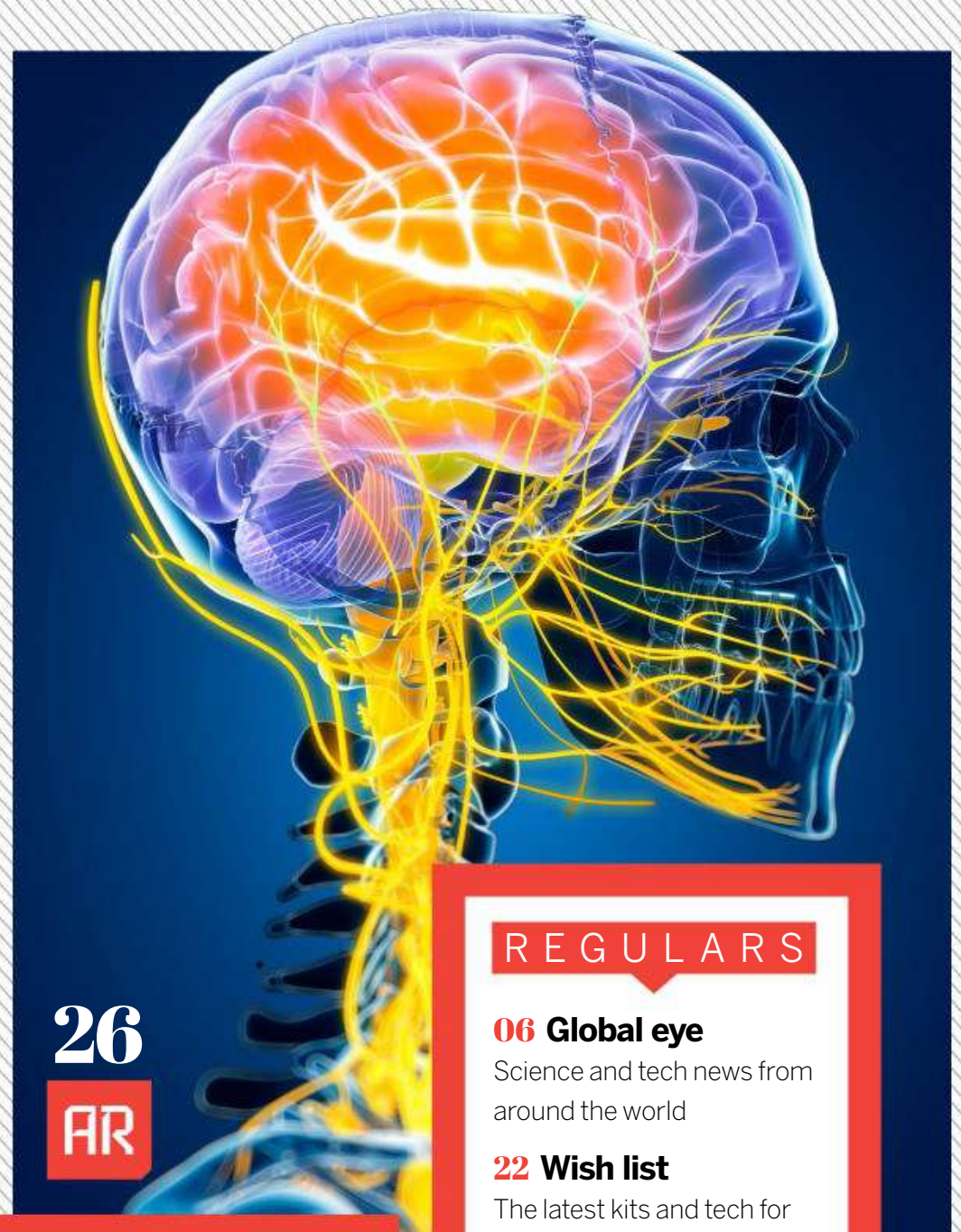

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MEET THIS ISSUE'S EXPERTS

MARK SMITH
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

MIKE JENNINGS
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

LAURA MEARS
Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

DR ANDREW MAY
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

JAMES HORTON
James works primarily in microbiology. He's an experienced science journalist, having written for a number of science magazines.

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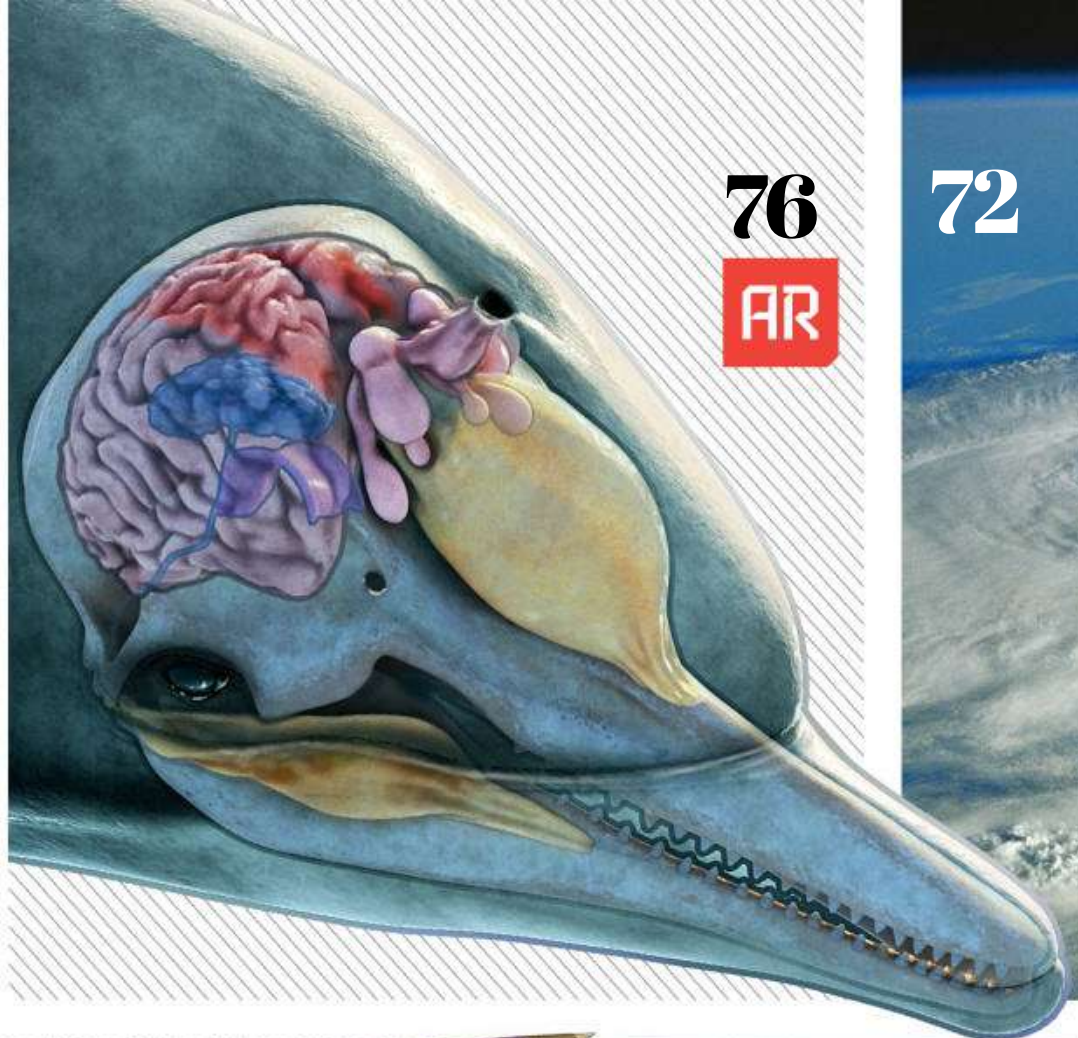

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Firework eruption

The summit crater of Batu Tara sits on top of the larger stratovolcano, which reaches to around 3,000 metres below sea level. This highly active volcano frequently releases incandescent bombs of lava that radiate from the volcano's vent. This type of explosion is known as a strombolian eruption, where basaltic magma and gas is ejected hundreds of metres into the air in firework-like blasts.

© Getty

Stellar clusters

Around 160,000 light years away in the Large Magellanic Cloud is this double cluster of thousands of stars, called NGC 1850. The main cluster in the centre of the image is around 50 million years old. Weaving throughout the stars are ribbons of hydrogen gas, which can be seen in this image in red and pink. These are believed to be the remnants of a supernova explosion.

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Plant feeding tubes

This is the stem of a nasturtium, a colourful edible herb. The microscopic cross-section shows some of the most important structures in the plant's physiology, called vascular bundles. These bundles are responsible for transporting water and soluble nutrients around the entire plant for growth. They work in a similar way to how veins and arteries supply the human body with vital blood.

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Olivar's squat lobster

Meet one of the strangest crustaceans in the sea, the Olivar's squat lobster (*Munida olivarae*), also known as the google-eyed fairy crab. These crabs spend their time nestled in tiny, rocky coral holes and are rarely seen outside of their homes. They can grow up to six centimetres long and use their lengthy claws, covered in spines, to catch their prey.

© Getty

A new scan of the Great Pyramid of Giza could shed light on its mysterious voids

HISTORY

Hidden chamber discovered in the Great Pyramid

WORDS **OWEN JARUS**

A new ultra-powerful scan of the Great Pyramid of Giza using cosmic rays could reveal the identities of two mysterious voids inside. The largest of the two voids is located just above the grand gallery, a passageway that leads to what may be the chamber of the pharaoh Khufu, and is about 30 metres long and six metres in height. Archaeologists are uncertain as to what they will find in the void, which could be one large area or several small rooms. They also hope to find out the function of that void – the most fantastic possibility is that the opening is the hidden burial chamber of Khufu. A more mundane possibility is that the cavity played some role in the building of the pyramid.

Constructed for the pharaoh Khufu, the Great Pyramid of Giza is the largest pyramid ever constructed in ancient Egypt and is the only surviving wonder of the ancient world. Between 2015 and 2017, the ScanPyramids project ran a series of scans that analysed muons, cosmic particles that regularly fall on Earth, to detect any voids. Those scans revealed both of the voids in 2017. Now a new team is planning to scan the Great Pyramid again, but this time with a more powerful system that will analyse muons in greater detail. Muons are negatively charged elementary particles that form when cosmic rays collide with atoms in Earth's atmosphere. These high-energy particles constantly rain down on Earth; because they behave differently when interacting with, say, stone versus air, researchers can use super-sensitive detectors to pinpoint the particles and map areas they can't physically explore, as with the Great Pyramid.

"We plan to field a telescope system that has upwards of 100 times the sensitivity of the equipment that has recently been used at the Great Pyramid," researchers wrote in a preprint paper, yet to be reviewed by other scientists in the field. "Since the detectors that are proposed are very large, they cannot be placed inside the pyramid. Therefore our approach is to put them outside and move them along the base. In this way we can collect muons from all angles in order to build up the required dataset," the team wrote.

"The use of very large muon telescopes placed outside can produce much higher resolution images due to the large number of detected muons," they added. The detectors are so sensitive, the researchers pointed out, they might even reveal the presence of artefacts inside the voids. If "a few cubic metres are filled with material," such as pottery, metals, stone or wood, "we should be able to distinguish that from air," said Alan Bross, a scientist at the Fermi National Accelerator Laboratory.

A Triceratops that died 67 million years ago in what is now Montana left behind a spectacular fossil that's now the centrepiece of a new exhibit

HISTORY

MOST INTACT TRICERATOPS FOSSIL GOES ON DISPLAY

WORDS **MINDY WEISBERGER**

Nicknamed 'Horridus' after the species name *Triceratops horridus*, the fossil, which is about 85 per cent complete, made its public debut at the Melbourne Museum in Australia in a new exhibit last month.

Horridus was a herbivore, or plant-eating dinosaur, that lived during the Cretaceous period, and it grew to an impressive size. The fossil contains more than 260 bones and weighs more than 1,000 kilograms. It measures nearly seven metres long and stands over two metres tall. The skull, which is 98 per cent complete, is tipped with two slender horns at the brow and a stubby horn atop the nose. The neck frill spans 1.5 metres, and the skull weighs about 261 kilograms.

Upon arriving at Melbourne Museum, fossil preparers measured, labelled and 3D-scanned each bone before the skeleton was assembled for display. While many articulated Triceratops skeletons are exhibited around the world, only Horridus and a handful of others are made of bones that came from one individual animal.

"This is the Rosetta Stone for understanding Triceratops," said Erich Fitzgerald, a senior curator of vertebrate palaeontology at Museums Victoria. "This fossil comprises hundreds of bones, including a complete skull and the entire vertebral column, which will help us unlock mysteries about how this species lived 67 million years ago," he said.

ANIMALS

Scientists discover a new rainbow-coloured fish

WORDS **HARRY BAKER**

Researchers have described a stunning multicoloured wrasse in the Maldives as a newfound species after the fish spent decades being misidentified as a closely related species. The rainbow-coloured fish lives among unusually deep coral reefs known as 'twilight reefs'.

The newly described species, which has been named the rose-veiled fairy wrasse (*Cirrhilabrus finifenmaa*), resembles the red velvet fairy wrasse (*Cirrhilabrus rubrisquamis*), which is found across the western Indian Ocean. Both species live on mesophotic coral reefs, which grow much deeper than most tropical coral reefs, between 30 and 149 metres below the ocean's surface. Scientists collected the first *C. finifenmaa* specimen in 1990, but its similarity to *C. rubrisquamis* meant that experts didn't recognise the fish as a distinct species.

Recently, after noticing this mistake, another group of researchers collected specimens of *C. finifenmaa* from the twilight reefs surrounding the Maldives. When they compared the new specimens to *C. rubrisquamis* wrasses, they found that *C. finifenmaa* females, which are mainly red, pink and blue, were a close match to *C. rubrisquamis*. However, *C. finifenmaa* males weren't – their scales featured more orange and yellow hues. The researchers also found that *C. finifenmaa* has a different number of scales in certain body regions and taller dorsal spines than its lookalike cousin. DNA analysis confirmed that these two species were genetically distinct.

The species name 'finifenmaa' means 'rose' in the Maldives' Dhivehi language, referencing not only the beautiful pink and red colours displayed by the new species, but also the Maldives' national flower. This marks the first time that a Maldivian researcher has chosen the scientific name of a local fish species, despite the island chain being home to around 1,100 fish species. "It has always been foreign scientists who have described species found in the Maldives, without much involvement from local scientists," said Ahmed Najeeb, a biologist at the Maldives Marine Research Institute.

However, the researchers suspect that the Maldives' *C. finifenmaa* population may be in danger of declining. *C. rubrisquamis* wrasses have long been targeted by local fishers to be sold for the global aquarium trade, which generates around £250 million ($330 million) each year. Because the two wrasse species look so much alike, *C. finifenmaa* may also be affected by such activities.

Did you know?

Triceratops means 'three-horned face'

A male rose-veiled fairy wrasse displaying its rainbow hues

© Getty / Museums Victoria / Yi-Kai Tea/California Academy of Sciences

Artist's illustration of Planet Nine, a world about ten times more massive than Earth that may lie undiscovered in the far outer Solar System

SPACE

Planet Nine is still missing

WORDS **BRANDON SPECKTOR**

Astronomers searching for our Solar System's elusive Planet Nine, a theoretical world that may lurk deep in a cloud of icy rocks far beyond the orbit of Neptune, have come up short once again. In a recent study, researchers pored over six years of telescope data in an attempt to identify potential signs of Planet Nine in the southern sky. Captured with the Atacama Cosmology Telescope (ACT) in Chile between 2013 and 2019, the observations covered about 87 per cent of the sky visible from the Southern Hemisphere.

While the team identified more than 3,000 candidate light sources located between 400 and 800 astronomical units (AU) away – that's 400 to 800 times the distance between Earth and the Sun – none of those candidates could be confirmed as planets. However, the fruitless search doesn't disprove the theoretical planet's existence; it merely narrows down where that planet may be lurking and what its properties could be, the researchers said. Ultimately, the study covers between just 10 and 20 per cent of the planet's possible locations in the sky.

Astronomers first began searching for Planet Nine in 2016, noticing that six rocky objects beyond the orbit of Neptune clustered in a strange way, with the most distant points in their orbits located much farther from the Sun than the nearest points of their orbits. The team calculated that the gravitational pull of an unseen planet measuring five to ten times the size of Earth could explain the eccentricity in those rocks' orbits. Half a decade later, many teams have tried and failed to detect that theoretical world. The biggest hurdle in the hunt for Planet Nine is the sheer distance involved. While Pluto orbits between 30 and 50 AU from the Sun, the authors of the 2016 study estimated that Planet Nine could be anywhere between 400 and 800 AU away – so far away, in fact, that sunlight may not reach the planet at all.

That means there's little hope of detecting the cold, dark Planet Nine with standard visible-light telescopes. Instead astronomers turn to the likes of the ACT, which can search the cosmos in millimetre wavelengths, a short form of radio waves that come close to infrared radiation. Millimetre telescopes are often used to peer into dim, freezing gas clouds where new stars form, because such clouds don't absorb millimetre light. While this survey failed to turn up any compelling evidence, new millimetre telescope facilities, such as the Simons Observatory that's currently under construction in Chile's Atacama Desert, will continue the search with even more sensitive telescopes.

PLANET EARTH

Antarctic sea ice is at a record low

WORDS **PATRICK PESTER**

Antarctic sea-ice coverage was at a record low in February 2022. But the amount of sea ice varies considerably each year and climate change is not necessarily to blame. On 25 February, sea-ice extent around Antarctica shrank to less than 772,000 square miles for the first time since scientists began recording it in 1979. While warming global temperatures may be a factor, sea ice is highly variable. The shrinking is likely natural, and partly due to strong winds pushing some sea ice farther north into warmer waters.

Sea ice is frozen seawater that floats on the ocean. Unlike icebergs and other ice formations that break away from land, sea ice forms on the ocean and is usually covered in snow. The new data captured the annual late-summer minimum sea-ice extent, which gives a measurement of the area of ocean that has sea ice when coverage is at its lowest for the year after the ice melts. Sea ice varies from year to year, and researchers have not found a statistically significant trend in one direction or another using satellite data.

This year was the lowest minimum sea-ice extent on record, but the highest minimum sea-ice extent was recorded in 2015. Satellite images of the Arctic show a clear, linear sea-ice decline over the past 44 years. A comparison of satellite records from February 1979 and February 2022 showed that Arctic sea-ice extent has declined by 703,000 square miles.

Antarctic sea ice floats in the water in the Lemaire Channel off Antarctica

HEALTH

Sleeping with a light on may be bad for your heart

WORDS NICOLETTA LANESE

Just one night spent sleeping in a moderately lit room can lead to a higher heart rate during the night and insulin resistance the next morning. A new study included two groups of ten healthy adults. One group slept in dimly lit rooms for two consecutive nights and the other slept in dimly lit rooms one night and then moderately lit rooms the next. The moderately lit rooms were illuminated with a 100 lux overhead light, which is about as bright as it would be on an overcast day. A 100 lux light could also be compared to a lit television screen in a darkened room or a standard street light shining through a thinly veiled window.

All the study participants wore heart monitors to sleep. On the second night, the group that slept in moderately lit rooms showed a marked increase in heart rate while they slept compared to the night before. The group that slept in dim lighting both nights showed no significant change. "We showed your heart rate increases when you sleep in a moderately lit room," said Daniela Grimaldi, assistant professor of neurology at Northwestern University. "Even though you're asleep, your autonomic nervous system is activated." The autonomic nervous system regulates involuntary bodily processes such as breathing, heart rate, pupil dilation and digestion, as well as the fight-or-flight response.

If the autonomic nervous system is driving up heart rate during the night, "that's bad," Grimaldi said. "Usually your heart rate, together with other cardiovascular parameters, are lower at night and higher during the day." Researchers also ran several tests to estimate the participants' insulin resistance each morning of the study after they awoke. The hormone insulin normally helps cells take in glucose, or sugar, from the bloodstream. But when cells are resistant to insulin, they don't take in glucose as readily, and the body produces more and more insulin to compensate. Over time, cells become resistant to even these sky-high insulin levels, which causes blood sugar levels to soar. On the first morning, after they'd slept in dimly lit rooms, both study groups scored about the same on the insulin resistance tests.

These tests included the homeostatic model assessment of insulin resistance (HOMA-IR), a calculation that takes fasting insulin and blood sugar levels into account, as well as direct tests of how the body responds to glucose, called an oral glucose tolerance test (OGTT), and the Matsuda insulin sensitivity index. On the second morning, the group that slept in the moderately lit room scored worse on these tests, while the group that slept in dim light scored about the same or better as the day before. "Exposure to a single night of [moderate] room light during sleep increased measures of insulin resistance the next morning," the researchers wrote. This study is limited in that it only included 20 people and only monitored the participants for two days and nights. "People shouldn't assume that they need to change their sleeping habits unless these results are borne out in a larger trial," Jim Horne, a UK-based neuroscientist specialising in the study of sleep, said.

The study monitored 20 participants while they slept with the light on

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GLOBAL EYE

SPACE

INTERGALACTIC SHOCK WAVE IS BIGGER THAN THE MILKY WAY

WORDS **BRANDON SPECKTOR**

Located about 730 million light years from Earth, Abell 3667 is a galaxy cluster in chaos. It's composed of two clusters of colliding galaxies. This has created an enormous disturbance in the region: a gargantuan shock wave flaring out either side of the merging cluster and visible only in radio wavelengths. A recent study offers the most detailed picture ever of this enormous wave. Using the MeerKAT radio telescope array in South Africa, researchers imaged both halves of the shock wave's radio component, also called 'radio relics'.

The shock wave first blasted into being about 1 billion years ago, when the two galaxy clusters that make up Abell 3667 first collided. Galaxy clusters are the most enormous gravitationally bound structures in the universe; when two of them merge, they release the largest amount of energy in a single event since the Big Bang. As the wave shot electrons into space at near-light-speed, the particles tore through magnetic fields in the region, emitting the twin arcs of radio waves. The radio arcs each move at more than 3.3 million miles per hour and are about 13 million light years apart from each other, and each have been measured to be 60 times larger than the entire Milky Way galaxy.

The northern shock wave glows in radio wavelengths as electrons blast through interstellar space

HISTORY

14th-century sarcophagus found at Notre-Dame

WORDS **LAURA GEGGEL**

Archaeologists at Notre-Dame Cathedral in Paris, which caught fire nearly three years ago, have discovered a previously unknown 14th-century leaden sarcophagus along with other burials. It's not clear who was buried in the sarcophagus, but it was likely someone important. The characteristics and location of the sarcophagus suggest that it holds the remains of a high dignitary. The iconic 12th-century cathedral went up in flames during a renovation and restoration project in April 2019.

Since then, the French government has moved forward with a reconstruction that will restore the cathedral's historic Gothic architecture, a feat that church officials hope will be completed by 2024, when Paris is slated to host the Summer Olympics. In the latest step of the restoration, workers had planned to put up scaffolding ahead of reconstructing the cathedral's burned spire. Before the workers could erect the scaffolding, however, archaeologists surveyed the site to look for any artefacts in the way that might be damaged. During the excavation the team focused on the transept, the part of the cathedral where the floor runs perpendicular to the main building, forming a cross.

The transept was covered with a stone layer that dates to no later than the 18th century. Beneath this, archaeologists found many burials from different layers, indicating that this spot was used as a burial ground for a long period of time. These burials dated from the 14th century and rest in soils that may date back to the beginning of the 13th century. Among the many burials, archaeologists also found the fully preserved, human-shaped leaden sarcophagus. Its placement at the cathedral's transept suggests that the interred person had elite status, while its underground layer indicates that it dates to the 14th century at the latest.

The excavation revealed another extraordinary find: a pit filled with painted sculptures that were once part of Notre-Dame's rood screen, the ornate partition that divides the chancel and nave, or the different ends of the cathedral. This rood screen was built in around 1230 CE and destroyed at the beginning of the 1700s. French architect Eugène Viollet-le-Duc previously discovered other fragments of this rood screen, which are now on display at the Louvre Museum, also in Paris. The new discovery will likely provide new data on this rood screen and on the quality of its painted decoration.

A 14th-century lead sarcophagus unearthed at Notre-Dame Cathedral in Paris

Images from NASA's Chandra X-ray Observatory and ground-based optical telescopes show a filament of matter and antimatter extending from a pulsar

SPACE

NASA caught a dead star spewing antimatter

WORDS MINDY WEISBERGER

A small pulsar belched out an enormous beam of matter and antimatter particles that streamed for 40 trillion miles across the Milky Way. Astronomers detected the cosmic particle trail in images captured in X-rays by NASA's Chandra X-ray Observatory in space and in optical light by the Gemini North telescope in Hilo, Hawaii. Observations of X-ray filaments emitted by pulsars are rare – to date only a handful have been detected.

Pulsars are dense, shrunken remnants of giant collapsed stars that emit radiation pulses as they spin, and they have powerful magnetic fields that are generated by their rapid rotation. This pulsar, known as PSR J2030+4415, spins about 1,600 light years from Earth and is relatively tiny – just ten miles in diameter, about the size of a city.

This fast-spinning pulsar travels through space at about 500,000 miles per hour and rotates about three times per second; as it spun around, charged particles escaped as a streaming filament that was then captured in telescope images. The huge scope of PSR J2030+4415's particle stream could explain why the Milky Way contains so many positrons, the antimatter counterparts of electrons.

Images of PSR J2030+4415 captured in 2020 and 2021 revealed the extraordinary length of the filament and also showed particles in a cloud-like halo surrounding the pulsar. "It's amazing that a pulsar that's only ten miles across can create a structure so big that we can see it from thousands of light years away," said Martijn de Vries, a postdoctoral scholar at the Kavli Institute for Particle Physics and Cosmology at Stanford University. "With the same relative size, if the filament stretched from New York to Los Angeles, the pulsar would be about 100 times smaller than the tiniest object visible to the naked eye."

Pulsars have powerful magnetic fields that usually confine whipping winds of charged matter and antimatter particles close to the collapsed star. As a pulsar travels through space, its magnetic field interacts with nearby solar winds and gases, which build up as they travel ahead of the pulsar like a wave of water pushed along by the prow of a boat. About 20 to 30 years ago, something disrupted the momentum of the wave produced by PSR J2030+4415 and the pulsar slammed into it; the collision likely triggered a particle leak and sprayed a stream of particles into space. "The pulsar wind's magnetic field linked up with the interstellar magnetic field and the high-energy electrons and positrons squirted out through a nozzle formed by connection," said Roger Romani, a physics professor at the Kavli Institute.

Did you know?
Pulsars are a rapidly spinning type of neutron star

Most of the matter in the universe is normal matter; antimatter is matter with the opposite electric charge. In pulsars, a combination of speedy rotation and strong magnetic fields creates a perfect storm of powerful radiation and particle acceleration, producing paired electrons and positrons – matter and antimatter. Astronomers previously detected pockets of antimatter in our home galaxy in the form of positrons, but the origins of this local antimatter have been elusive. However, with the discovery of PSR J2030+4415's staggeringly long trail, the study authors suspect that this tiny pulsar could be a source.

© Getty / Francesco de Gasperin/SARAO / NASA/CXC/Stanford Univ./M. de Vries; Optical: NSF/AURA/Gemini Consortium

SPACE

Astronomers detect largest organic molecule ever

WORDS BRANDON SPECKTOR

Astronomers have detected the largest organic molecule ever seen in a cloud of planet-forming dust, potentially offering new insights into the way that the building blocks of life end up on planets. Using the Atacama Large Millimeter/submillimeter Array (ALMA) telescope in Chile, researchers studied the light emitted by different molecules in the lopsided ring of dust and ice surrounding the young star Oph-IRS 48, located about 444 light years from Earth in the constellation of Ophiuchus.

Within the dusty ring, the researchers saw clear traces of an organic compound called dimethyl ether, a large molecule that's commonly detected in stellar nurseries – cold, dusty regions of space where new stars form – and is a precursor to crucial building blocks of life such as amino acids and sugars.

Made of nine atoms, dimethyl ether is the largest molecule ever detected in a planet-forming ring, the team said. This discovery helps fill in the story of how complex organic molecules make their way from star-forming regions of space to planet-forming regions, then ultimately to planets themselves. "From these results, we can learn more about the origin of life on our planet and therefore get a better idea of the potential for life in other planetary systems," said Nashanty Brunken, a master's student at Leiden University in The Netherlands.

The star IRS 48 caught astronomers' attention about a decade ago thanks to the massive, cashew-shaped ring of ice and dust surrounding it. Researchers called this lopsided region a 'dust trap', a high-pressure area where tiny particles of dust can clump together into ever-larger bodies such as asteroids and eventually planets.

Astronomers have long suspected that large compounds like dimethyl ether arise in star-forming regions of space, which are cold enough that simple atoms and molecules can stick onto tiny dust particles, forming an ice layer. As they clump together, those icy molecules can undergo chemical reactions, forming larger and more complex organic compounds. But dust traps, like the one surrounding IRS 48, may also serve as deep-space laboratories where molecules can undergo chemical reactions. Within that nut-shaped disc there is also a reservoir of ice, which appears to be full of icy dust grains harbouring organic molecules. When radiation from the nearby star sublimated that ice into gas, those frozen organic compounds were released, making them detectable to telescopes back on Earth.

Studying the light emitted by those molecules, the team identified the signature of dimethyl ether, as well as several other organic compounds never seen in a planetary disc before, including methyl formate, another organic compound that serves as a building block for larger life-essential molecules. "What makes this even more exciting is that we now know these larger complex molecules are available to feed forming planets in the disc," said Alice Booth, also a researcher at Leiden Observatory. "This was not known before as in most systems these molecules are hidden in the ice."

The star system IRS 48 is known for its cashew-shaped 'dust trap', seen in this artist's representation

King cobras, which may be four distinct species, are the longest venomous snakes in the world

ANIMALS

King cobra is actually four species

WORDS **CAMERON DUKE**

The imposing king cobra (*Ophiophagus hannah*) is the world's biggest venomous snake and can measure over five meters long. It inhabits a sizable kingdom across the Asian tropics, stretching from Indonesia to India. However, new research reveals that the king cobra's massive domain is not ruled by just one species... rather there are four distinct species of king cobra. The four proposed species, which are yet to be officially named, are the Western Ghats lineage in southwestern India, the Indo-Chinese lineage in Indonesia and western China, the Indo-Malayan lineage spanning India and Malaysia and the Luzon Island lineage, found in the Philippines.

Despite their similarities, the cobras found in this vast geographic range have some physical differences. For example, adult cobras in Thailand have roughly 70 bright, off-white ring markings on their bodies, while cobras in the Philippines only have a few dull rings. The snakes demonstrate regional differences in their behaviours, too. The king cobra is the only snake species to gather material and build nests for its eggs, but the eggs in that nest might be treated differently depending on the region. In some regions the mother slithers off after laying the eggs, while in other places she might incubate them in the same way a bird would.

But it's not just physical and behavioural differences that separate these four lineages; researchers needed to know if the king cobra populations were genetically different. Gathering such data on the world's biggest venomous snake was a challenging task. Biologist P. Gowri Shankar, a king cobra expert at the Kālinga Centre for Rainforest Ecology in Karnataka, India, spent years studying these snakes.

Eventually, Shankar and his team have been able to gather enough genetic material to analyse DNA from 62 king cobra specimens found throughout the ranges of the population variants. Researchers gathered scales from live snakes and collected muscle tissue from dead snakes that were discovered as roadkill. They even managed to recover DNA from long-dead museum specimens.

Initially, researchers looked at mitochondrial genes, which are passed from mother to offspring, and they identified four distinct lineages. They then looked at differences in nuclear DNA between the four candidate lineages. It was discovered that the four lineages were not regional variants of one species, but were instead genetically separate from one another. "The overlap of genetic diversity with separate geographic regions suggests the species have been evolving separately without any gene flow between them," Shankar said.

HISTORY

SKULL OF SEA SERPENT-LIKE MAMMAL UNCOVERED

WORDS **BRANDON SPECKTOR**

Researchers digging in Peru's Ocucaje Desert have uncovered the skull of an enormous marine predator thought to be the ancestor of modern whales and dolphins. 1.2 metres long and lined with knife-like teeth, the skull appears to be a new species of Basilosaurus, a genus of ferocious marine mammals that lived some 36 million years ago during the Eocene epoch. From snout to tail the creature probably measured about 12 metres long, or about the size of a city bus. For now researchers are calling this ancient beast the 'Ocucaje Predator'. It won't be formally named until the team publishes a scientific description of the species in a peer-reviewed journal.

The Ocucaje Desert was once the bottom of an ancient ocean. Basilosaurus and its ferocious cousins swam these seas as apex predators from 41 million to 34 million years ago, gliding through the water with bodies that resembled enormous snakes, but with a large pair of flippers near their heads. Basilosaurus means 'king lizard', and the creature's serpentine skeleton was once mistaken for a marine reptile. Scientists now know that Basilosaurus was a mammal – a fully aquatic cetacean like the whales and dolphins that would follow it millions of years later.

The skull of the newfound Basilosaurus species sits on display at the National University of San Marcos in Lima, Peru

© Getty / ESO/L. Calçada

WISH LIST

The latest for OUTDOOR EXPLORERS

KLETTERSACK

WWW.TOPODESIGNS.COM $169 (APPROX. £128.70)

Hiking out in the wilderness wouldn't be possible without a good bag on your back, and the classic Klettersack is one of the most reliable out there. This backpack is built to last while facing off against the elements, with its robust 1,000D Cordura exterior, coated pack cloth liner for extra water resistance and heavy-duty plastic hardware. The bag has a 25-litre capacity for all your outdoor essentials, as well as side pockets for easy access to water bottles. If you're just out for a hike and want to keep your belongings safe and secure or you're on an outdoor adventure, this functional and fashionable bag is a great companion. The Klettersack does come with a high price tag, however, especially considering other backpacks offer the same capacity at a much more affordable price.

ALPENGLOW 500

WWW.BIOLITEENERGY.COM

£79.99 / $79.95

Lights are essential when you're out camping during the night, so BioLite has created an illuminating lantern. The AlpenGlow 500 is a multicoloured USB lantern that can deliver a bright light of up to 500 lumens with its LED bulb. But what makes this so different from other camping lights is the built-in ChromaReal LED technology. This feature means the lantern can accurately replicate the colours of your environment, such as a sunset, with a natural-looking glow. The lantern is also dimmable and can move through cool and warm white tones. Giving it a quick shake will give you access to a host of different lighting modes, such as a candle flicker, or to cycle through different colours. This rechargeable lantern also has a five-hour battery life when set on high and up to an impressive 200 hours when set to low.

JBL CLIP 4

UK.JBL.COM / JBL.COM

£49.99 / $79.95

The Clip 4 is one of the simplest portable speakers to carry around on a hike. Simply buckle it to your bag with the handy carabiner and hit play. This Bluetooth speaker easily links to your smartphone for quick enjoyment of high-quality sound. The device only weighs 239 grams, so it's not going to weigh you down like some other heavy-duty portable speakers. The Clip 4 is also designed with the weather in mind and promises to be waterproof and dustproof. Its battery life is also pretty impressive for a portable speaker, boasting ten hours of playtime on a single charge.

CAMPSTOVE COMPLETE COOK KIT

WWW.BIOLITEENERGY.COM £288.88 / $274.80

BioLite always seems to be at the forefront of outdoor activities. Since its electricity-generating CampStove was released, it has created a whole host of new and exciting products perfect for high-tech camping – many of which you can now get in this complete kit. This comes with everything you need to create a kitchen in the woods. It includes the smokeless CampStove 2+, which uses the heat generated from the fire to charge a built-in battery that can be used to recharge other smart devices. The kit also features several accessories for the stove, including the 1.5-litre KettlePot, Portable Grill, CoffeePress and LED FlexLight. This portable kitchen ensemble means you have everything you need to make delicious food on the go.

MR300 PORTABLE MOSQUITO REPELLER

WWW.AMAZON.CO.UK / WWW.THERMACELL.COM

£22.60 / $24.99

Mosquitos are one of the most annoying aspects of enjoying the outdoors. This portable device is a great way to keep the pests at bay without the need for odorous sprays, promising a protection zone of around five metres. It works by heating a small pad saturated in repellent that sits below the metal grill. The heat source comes from fuel cartridges that last around 12 hours each. This does mean that cartridges will have to be replaced and extra will need to be carried, as well as more repellent mats, which last around four hours. Thermacell also offers several products that work on the same basis but use rechargeable batteries, although they aren't as portable as the MR300.

VSSL FLASK

WWW.VSSLGEAR.COM $115 (APPROX. £87.50)

If you thought this was just a standard insulated flask, think again. The VSSL Flask features a capacity of around 237 millilitres and comes with two handy stainless-steel shot glasses. The interior of the flask chamber is lined with shatterproof and non-permeable glass to maintain the quality and taste of your beverage. It's also a bit of a Swiss army knife of a flask and comes with an oil-filled precision compass, bottle opener and built-in LED flashlight with four modes. Designed to be used outdoors, the VSSL Flask is made from military-grade aluminium and food-grade stainless steel, meaning it'll withstand the odd bump and knock. The price tag on this flask-and-torch combo makes it more of a luxury accompaniment to your camping kit. However, considering that it's a multi-use gadget, it does save on much-needed backpack space.

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Explore the electrically charged network composed of billions of cells that coordinates your thoughts, feelings and actions from head to toe

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DID YOU KNOW? Electrical signals moving through neurons can travel at speeds of up to 120 metres per second

UNRAVELLING THE NERVOUS SYSTEM

Explore the electrically charged network composed of billions of cells that coordinates your thoughts, feelings and actions from head to toe

WORDS JAMES HORTON

Human beings are wonderfully complex. Relative to the numerous single-celled organisms on our planet, humans are gargantuan superstructures. We boast trillions of cells that work to assemble and maintain an array of specialised tissues, organs and bones. Together these form a single being that walks, talks, thinks and feels. This exceptional complexity is only made possible by a coordination centre that monitors and controls the actions of our human form. We refer to this coordination centre as the nervous system. Consisting of the brain, spinal cord and reams of nerves that connect them to the rest of the body, the nervous system is a truly vast and dense network of cells. Collectively, their function is to exchange and relay information through electrical impulses, giving us the power of thought and action.

Many prominent thinkers of Hellenic antiquity, the ancient civilisations around Greece, were obsessed with the complexities of human thought, constantly questioning and probing our understanding of ourselves and our place in the natural world. But some scholars, such as the Greek anatomist Galen, took a literal interest in our thoughts as well as a philosophical one, and decided to delve into dissected pigs in search of the organ that made thought possible. Through his studies, Galen collected evidence that centred the brain as the hub of thought, action and memory. As well as championing the brain as the nexus of the body, Galen also found nerve fibres in his pig subjects that spread outwards from the brain and into the periphery of their bodies. He even went as far to decipher that these nerves were not all the same, but specialised into sensory nerves that received signals and motor nerves that relayed instructions.

Many years later, but not too far away, Renaissance anatomists in Italy sliced and diced human brains to expand our knowledge of the organ. They discovered specialised regions like the pons, which acts as a 'bridge' connecting other brain regions, and the hypothalamus, which was found later to control hormone production. In England in the following century, Thomas Willis deduced that the brain controlled both voluntary and involuntary actions. Scholars were beginning to map the network of the nervous system, but how signals travelled around the network only became clear once Benjamin Franklin went out in a thunderstorm holding a metal key and a kite. In doing so, he performed an experiment that led to the discovery of electricity. This allowed scientists to reconsider how our nerves could be receiving and exchanging signals, eventually inspiring Emil du Bois-Reymond to confirm that electricity is the conduit by which information is exchanged in our neural pathways.

Centuries of research uncovered the highway of cells travelled by electrical signals to govern our actions, but chemical signals are required too. Neurons don't touch one another like a continuous road, but instead are separated by small gaps of water containing charged atoms, or ions. These gaps are known as synapses, which act as a bridge between neurons. Once a signal reaches the end of a neuron, at the axon, compounds called neurotransmitters are released. These cross the bridge and bind to the dendrites – the signal receivers of neighbouring neurons. This causes the next neuron to 'fire' its own electrical signal.

Despite this crossing happening between every neuron, the remarkable structure of the nervous system allows signals to be sent across the body in a fraction of a second. While we now understand much about the broader organisation of nerves and the way they function on a single-cell level, the nervous system continues to hold many mysteries for us to solve.

©Getty

SPECIAL

DIVISIONS OF THE NERVOUS SYSTEM

Learn the hierarchies of nerve structures that keep our bodies running and safe from harm

When we think of the nervous system, our thoughts immediately go to the brain. The brain is a hive of neuronal activity, with billions of interwoven neurons firing to preserve and recall memories, coordinate thoughts and speech and plan future actions. Along with the spinal cord, the bone-clad parts of our nervous system are called the central nervous system. The majority of our neurons are shielded behind protective fluid and bone, where they receive signals from and dictate to organs around the body. However, the signals sent from the central nervous system must have some means of reaching their target organs. For that they need to connect to nerves that stretch from the central nervous system all the way to the extremities of the body. This second network of nerves is called the peripheral nervous system. Together the central and peripheral form the major divisions of the nervous system.

The peripheral nervous system is responsible for many functions, and as such has numerous subdivisions that specialise in different tasks. The sensory, or afferent division receives signals from the periphery and carries these into the central nervous system. The motor, or efferent division transmits signals for actions outwards from the central nervous system to the peripheral organs and muscles. These motor functions come in two forms: somatic and autonomic.

Did you know?

Around 80 per cent of the brain's volume is filled with cells

Somatic functions are perhaps the easiest concept of the nervous system to grasp, as these dictate all of our voluntary actions, such as choosing to pick up a cup or jump on the bed.

Not all somatic motor functions are voluntary, however. Some are automatic, preprogrammed responses built into our bodies that help us cope with danger, known as somatic reflexes. You'll notice such a reflex when you accidentally touch a hot stove, step on a sharp object or something flies towards your eye – your body reacts before you're aware of it. Your hand pulls away, you hop onto the other foot or your eyelid slams shut. This is all the work of somatic reflexes, which can act incredibly quickly as they do not require voluntary input from the brain. Such reflexes can come in different flavours – pulling your hand away from danger is known as a flexor or withdrawal reflex, whereas stepping on a sharp object initiates a crossed-extensor reflex. This latter reflex automatically triggers multiple motor functions: as one leg retracts the other leg simultaneously expands and becomes more stable, preventing us from falling over.

The innate, hard-wired reflex responses of our peripheral nervous system help keep us safe from danger, but they are not the only automatic functions performed by the peripheral nervous system. When actions are not somatic, they are autonomic, which means they operate independently of conscious thought. Such processes include your heartbeat, the churning of food in the digestive tract by contracting muscles and respiration. While our brain can assume control of a few of these processes – think of holding your breath – autonomic functions will continue to operate even when we fall asleep or if we are knocked unconscious.

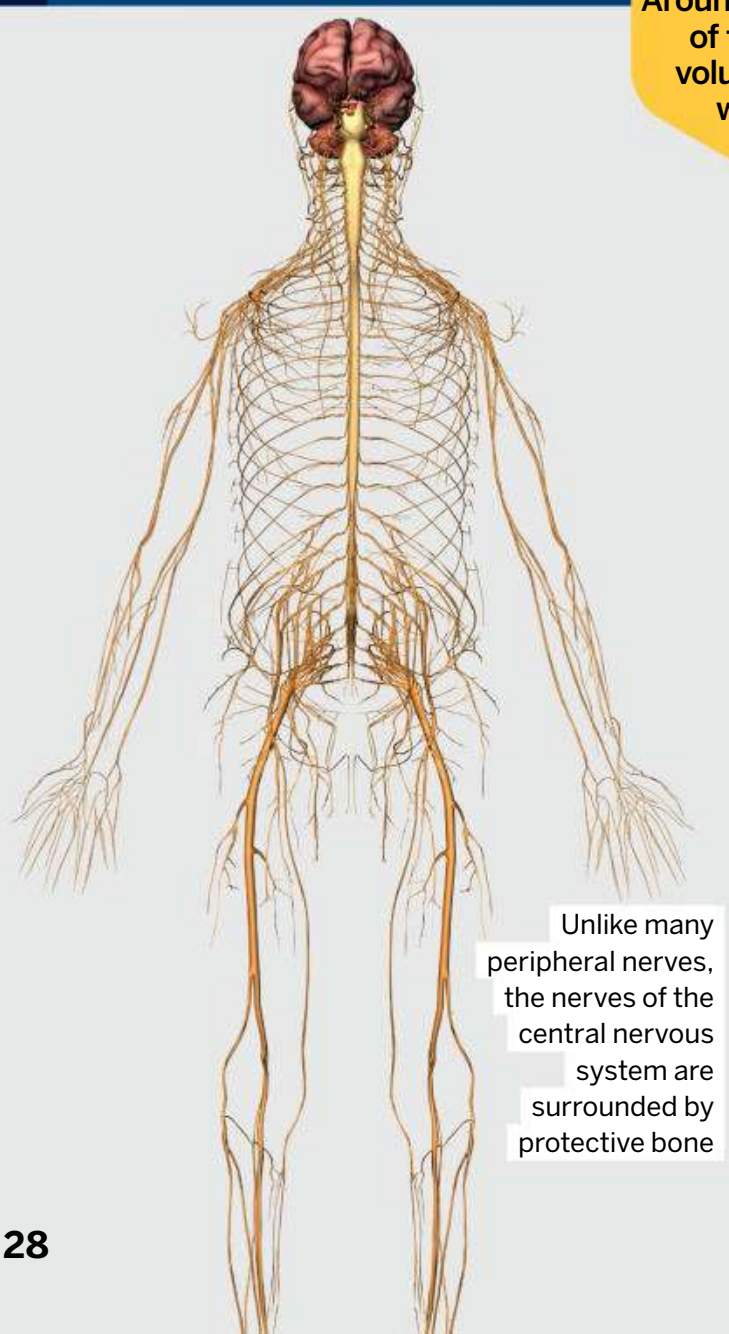
The processes that we cannot control, however, are by no means unchanging. Instead the organs under the control of the autonomic nervous system are regulated by a balance between the sympathetic and parasympathetic nervous systems. Depending on stimuli, these systems increase or decrease activity of our internal organs, helping to ensure our body is always ready to respond to the challenge at hand.

The brain is composed of three major regions; the cerebrum is the largest

REGIONS OF THE BRAIN

The brain makes sense of the world around us. It collects information from the five senses, interprets them and returns with instructions for the body's muscles and organs using its three major domains. The cerebrum is the largest part of the brain. It's split into two hemispheres, separated by a fissure that's visible when looking at the brain from above. The left hemisphere controls muscles on the right side of the body, and vice versa.

As well as motor control, the cerebrum is responsible for interpreting touch, vision and sound; controlling our sense of reasoning and determining our emotions. The cerebellum, nestled under the cerebrum, coordinates posture, balance and other muscle movements. Finally, the brainstem acts as a conduit, connecting the other regions of the brain to the spinal cord.

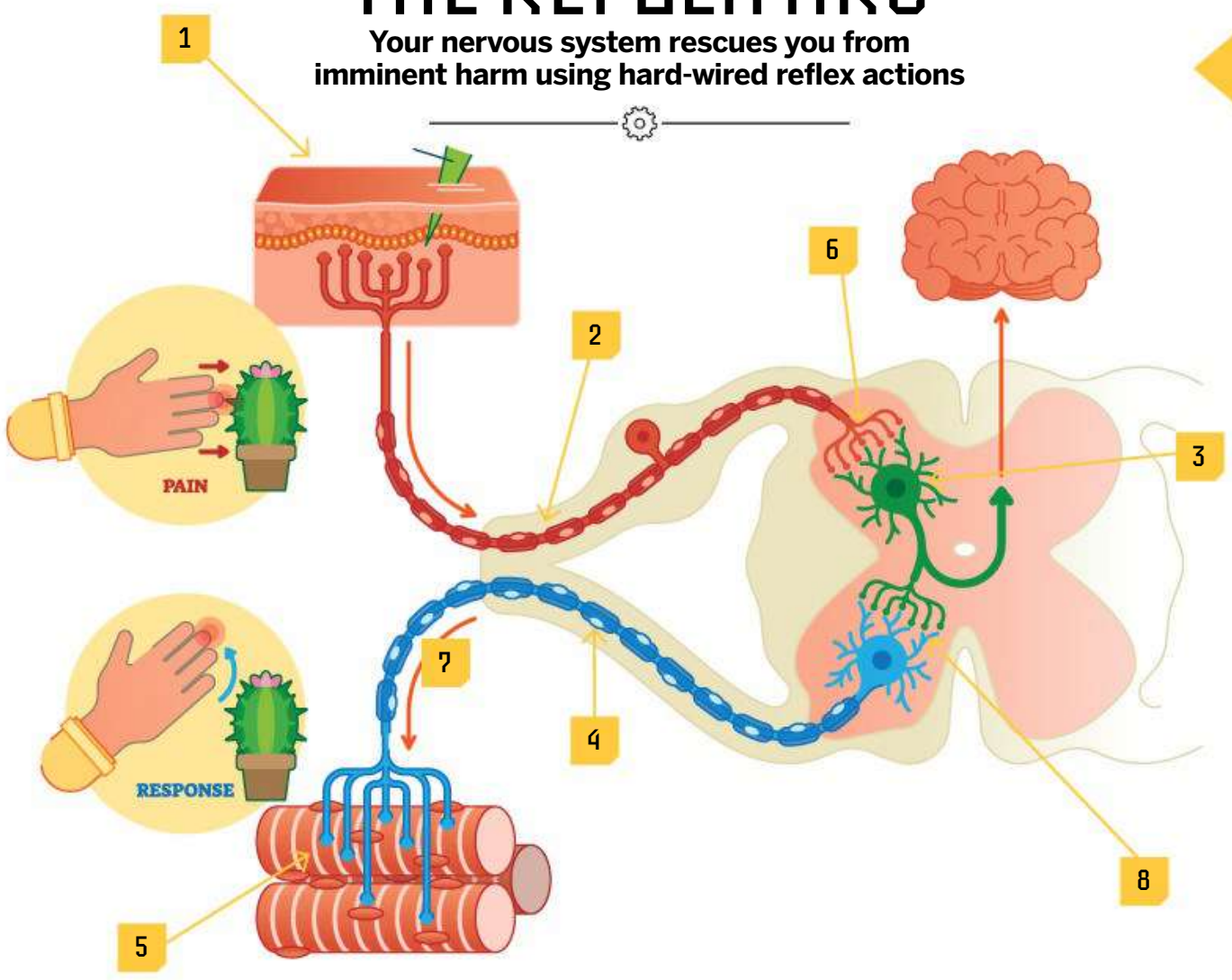


Unlike many peripheral nerves, the nerves of the central nervous system are surrounded by protective bone

DID YOU KNOW? The longest axons in the human body are found in the sciatic nerve, where they stretch for over a metre

THE REFLEX ARC

Your nervous system rescues you from imminent harm using hard-wired reflex actions



1 DETECTION
When your cells are at risk, such as when you accidentally touch a hot stove, receptors in your skin initiate a nerve impulse.

2 SENSOR NEURON
The nerve impulse travels from the dendrites of the sensory neuron towards the spinal cord.

3 INTERNEURON
Located in the spinal cord, the interneuron acts as a relay between the sensor and motor neurons, passing the impulse onto the latter.

4 MOTOR NEURON
The nerve impulse travels away from the spinal cord and towards the target muscle receptors via the motor neuron.

5 MOTOR FUNCTION
The signal forces muscles to contract, pulling your hand away from the heat source automatically without any conscious thought needed.

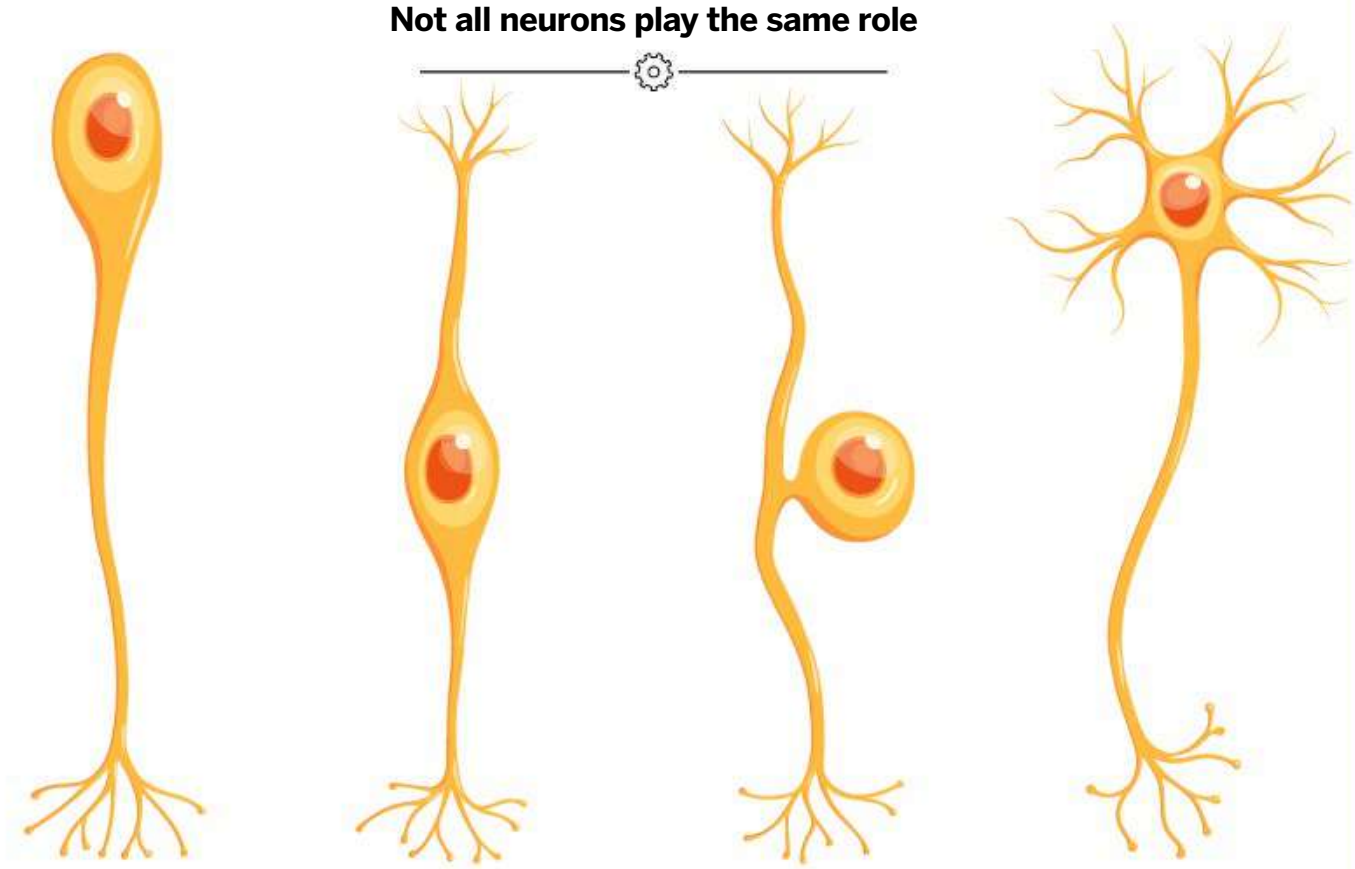
6 CLOSE NEIGHBOURS
The nerve impulse reaches connected neurons by 'jumping' across the synapse, a small gap that lies between them.

7 ONE-WAY TRAFFIC
The nerve impulse travels in one direction, starting at the sensory neuron and terminating at the end of the motor neuron.

8 POLYSYNAPTIC REFLEX
Reflexes can trigger either simple or complex responses. Polysynaptic reflexes can send signals to many muscles, allowing us to simultaneously contract them during a reflex.

TYPES OF NEURONS

Not all neurons play the same role



UNIPOLAR
A useful way of defining neurons is by the number of processes, or branches, that extend from the cell body. A unipolar neuron has just one axon branch.

BIPOLAR
These neurons have one dendrite and one axon extending in opposite directions. They are found up your nose and behind your eyes.

PSUEDOUNIPOLAR
These have one branch that extends from the cell body and splits into two branches. These neurons help connect the peripheral to the central nervous system.

MULTIPOLAR
Our most common type of neuron, which is numerous in the central nervous system. These possess many dendrites and a single axon.

©Getty

Did you know?

Cortisol reduces inflammation, helping keep nerves healthy

RELAXING OR TAXING

How we feel can affect our body in many ways

PARASYMPATHETIC NERVOUS SYSTEM

When we're free from periods of stress, our body responds by reverting to a more balanced state of rest and digest.

PUPIL CONSTRICTION
Stimulated muscarinic receptors in the eye cause contraction of the iris' sphincter muscle and the ciliary muscle, improving near vision.

STIMULATED SALIVA SECRETION
Parasympathetic stimulation causes the secretion of saliva components, including water, amylase and potassium ions.

CONSTRICTED AIRWAYS
The large tubes of the lungs, known as bronchi, constrict and stimulate secretions. These processes help protect the lungs from airborne irritants.

DECREASED HEART RATE
Parasympathetic inputs reduce the velocity of electrical conduction through the atrioventricular node of the heart, helping to slow contractions and reduce heart rate.

ACETYLCHOLINE
Much of the parasympathetic nervous system involves muscarinic receptors, which are activated by the molecule acetylcholine.

SPINAL CONNECTIONS
Organs connect to the sympathetic nerves via distinct ganglia that emerge from different regions of the spine.

SYMPATHETIC NERVOUS SYSTEM

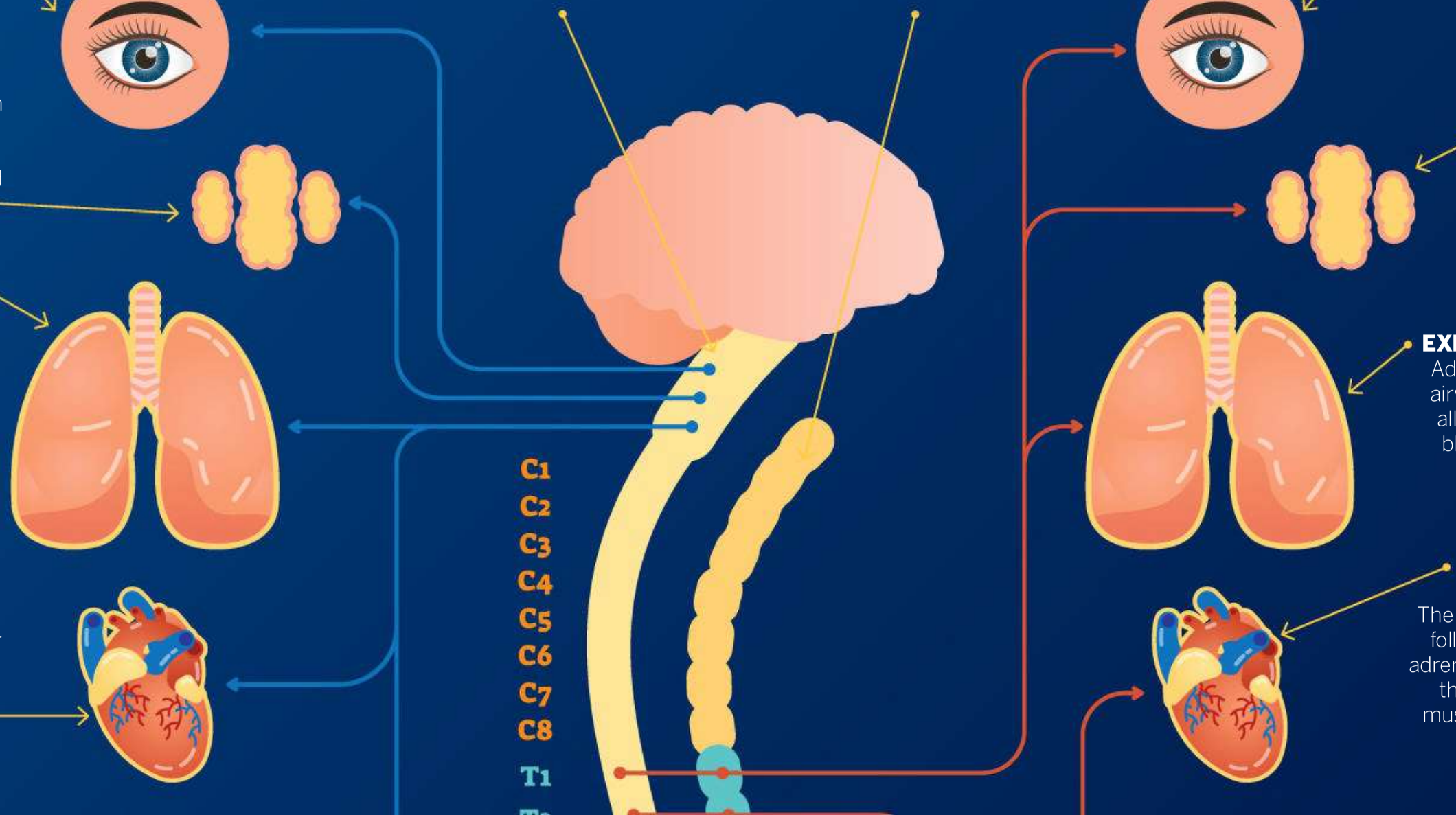
When we feel threatened, our instinctual reaction is known as the fight-or-flight stress response. The response induces a suite of physiological actions to help us cope with the challenge.

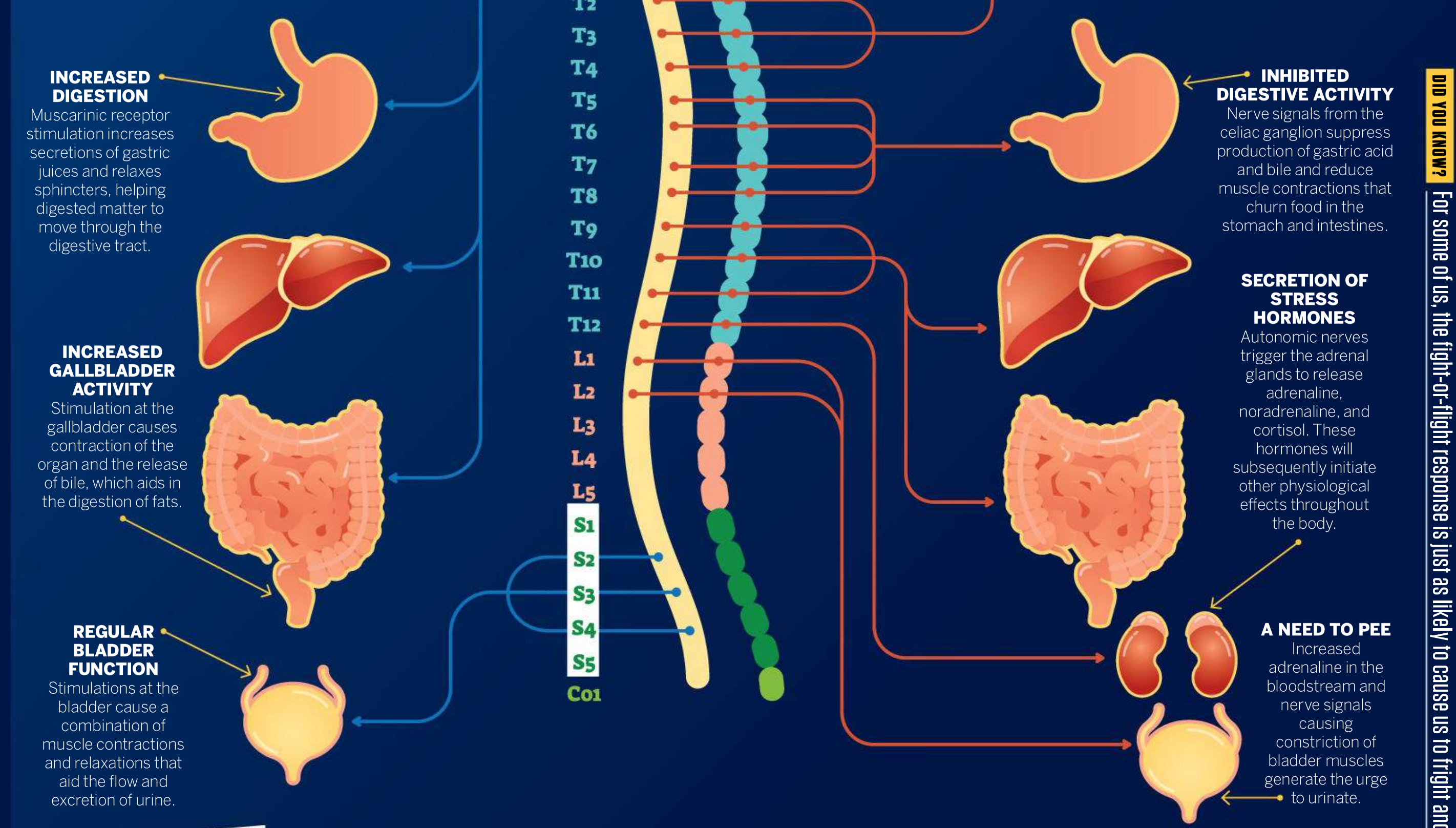
DILATED PUPILS
Adrenaline causes the pupils to widen, allowing the eyes to absorb more information from their surroundings.

INHIBITED SALIVARY GLANDS
Increased noradrenaline depresses the activity of saliva-producing acinar cells, helping to slow the digestive tract.

EXPANDED AIRWAYS
Adrenaline expands the airways lining the lungs, allowing the increased blood supply to more readily oxygenate.

INCREASED HEART RATE
The heartbeat quickens following exposure to adrenaline. This improves the blood supply to muscles and the brain.





INCREASED DIGESTION
Muscarinic receptor stimulation increases secretions of gastric juices and relaxes sphincters, helping digested matter to move through the digestive tract.

INCREASED GALLBLADDER ACTIVITY
Stimulation at the gallbladder causes contraction of the organ and the release of bile, which aids in the digestion of fats.

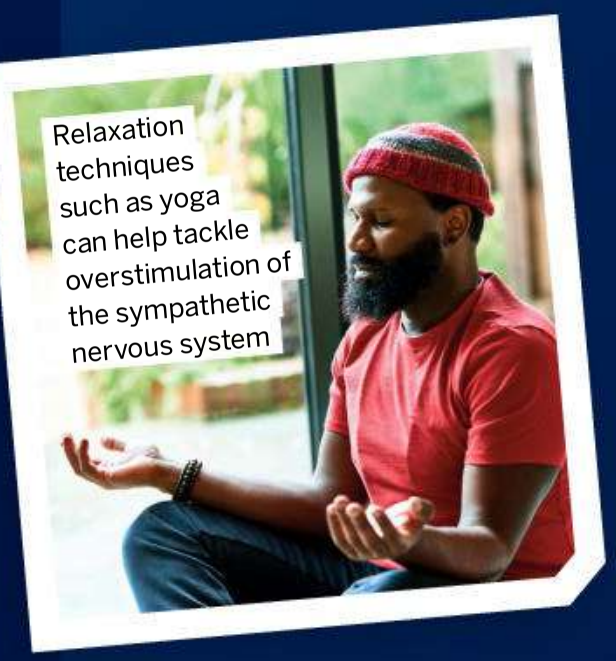
REGULAR BLADDER FUNCTION
Stimulations at the bladder cause a combination of muscle contractions and relaxations that aid the flow and excretion of urine.

INHIBITED DIGESTIVE ACTIVITY
Nerve signals from the celiac ganglion suppress production of gastric acid and bile and reduce muscle contractions that churn food in the stomach and intestines.

SECRETION OF STRESS HORMONES
Autonomic nerves trigger the adrenal glands to release adrenaline, noradrenaline, and cortisol. These hormones will subsequently initiate other physiological effects throughout the body.

A NEED TO PEE
Increased adrenaline in the bloodstream and nerve signals causing constriction of bladder muscles generate the urge to urinate.

DID YOU KNOW?
For some of us, the fight-or-flight response is just as likely to cause us to fright and freeze


Relaxation techniques such as yoga can help tackle overstimulation of the sympathetic nervous system

A BEAR OR A BOSS?

The fight-or-flight sympathetic stress response evolved to help humans survive encounters with predators. For much of our hunter-gatherer existence, as we explored the wilderness, discovered new environments and spread across the globe, we encountered all manner of dangerous fauna. For some of these encounters, quick reaction times would have been vital, helping those with an attuned response survive and pass on their genes to the next generation. Today most of us have little to fear from a hungry panther or a territorial grizzly bear, but the stress response is still routinely triggered, just by other means. Now many of us encounter the same intrinsic response when we run into an angry teacher in the corridor or when we have to present unexpectedly to our employer's CEO at the annual meeting.

Today fight or flight often triggers when we're socially anxious

© Getty

SPECIAL

DISEASES AND DAMAGE

As the connective network coordinating our body, damage to the nervous system can be debilitating

5 WAYS CORTISOL AFFECTS US

1 ALL OVER
Cortisol is the main stress-response agent in the body. Adrenaline and noradrenaline affect multiple organs, but cortisol is ubiquitous – most cells in the body possess cortisol receptors.

2 SOUNDING THE ALARM
The hypothalamus is a small region of the brain that monitors and regulates the stress response. During periods of stress, the hypothalamus signals the pea-sized pituitary gland to stimulate cortisol release.

3 GIVE ME FUEL
During the fight-or-flight response the body may need to act quickly, and for that it needs energy. Cortisol provides this fuel by stimulating the release of glucose.

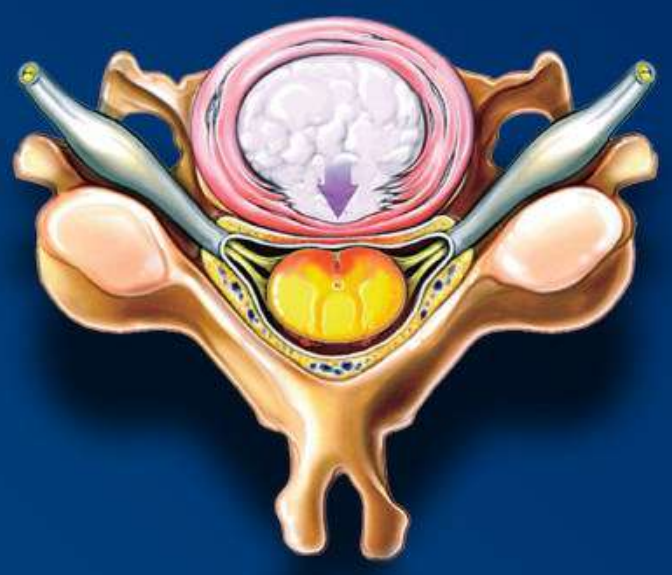
4 PRIORITIES
Non-vital organs for survival during periods of stress, such as the reproductive organs and immune system, are suppressed by cortisol, ensuring energy goes where it's needed most.

5 OVERSTRESSED
Cortisol aids during periods of stress and during daily function, but chronic stress overstimulates cortisol release. This risks a multitude of health problems, including anxiety and heart disease.

PINCHED NERVE

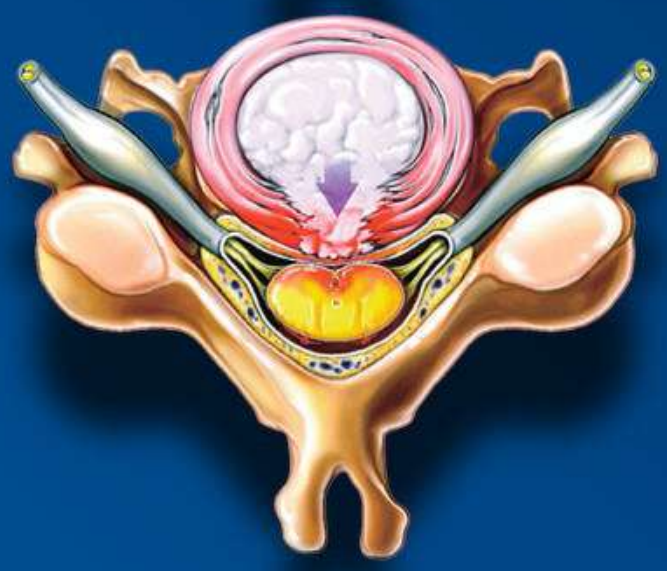
Excessive pressure from nearby tissue, including spinal discs, can 'pinch' nerves and interfere with their signalling. This results in pain, tingles, weakness or numbness as the nerve misfires

Spinal surgery can be used to treat herniated discs by alleviating pressure on the spinal cord



DISC BULGE
Spinal discs rest between the vertebrae of the spine, where they act as shock absorbers. They are formed of a softer centre and tougher outer band. As we age, cartilage in the disc dries and stiffens and the outer layer bulges.

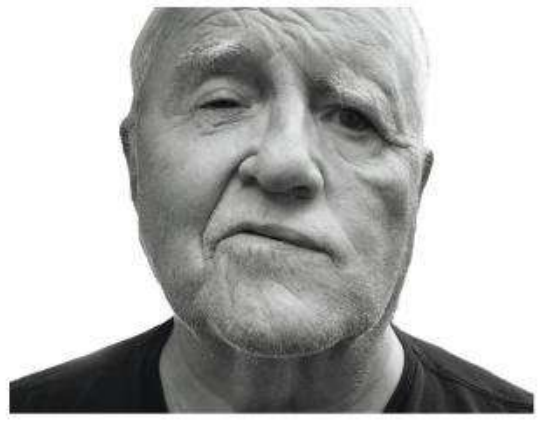
LATERAL DISC HERNIATION
When the outer layer of the spinal disc ruptures, it's known as a herniation, which allows the softer centre of the disc to ooze out. In laterally herniated discs, this places pressure on the nerve root of the spinal cord.



CENTRAL DISC HERNIATION
Central herniation can place excessive pressure on the spinal cord, causing severe compression in some cases. This can result in loss of motor function of the legs, affecting balance and strength when standing and walking.

BELL'S PALSY

Nerves spread out from the central nervous system to various organs and tissues, with each powering specific functions. Cranial nerve VII is known as the facial nerve, as it controls many of the muscles on our face, including blinking and smiling. When this nerve is inflamed, damaged or disrupted, Bell's palsy can occur, with the facial muscles becoming weakened or paralysed. This typically affects only one side of the face, causing drooping of the mouth on one side and a loss of control of an eyelid, giving the affected side a slack appearance. The full symptoms of Bell's palsy are often temporary, with some or total recovery of the affected areas occurring within six months. While it's not always clear what causes the cranial nerve to swell and Bell's palsy to occur, scientists believe that a recurring viral infection of the nervous system elicits an immune response that triggers the nerve damage.


Bell's palsy causes paralysis in part of the face due to swelling of cranial nerve VII

DID YOU KNOW? Mild cases of COVID-19 have recently been found to reduce brain size

MULTIPLE SCLEROSIS

Neurons are the agents of signalling in our bodies, but they don't work alone. Axons, which carry signals away from the neuron's cell body, are coated in a sheaf of myelin. Myelin sheaves are produced in the central nervous system by cells called oligodendrocytes, enabling myelin's function of protecting and facilitating nerve conductivity. In multiple sclerosis, an abnormal immune response within the central nervous system strips away the protective myelin and causes lots of nerve scarring, or sclerosis, which gives the disease its name. Research efforts are underway to treat the disease by encouraging myelin regeneration.

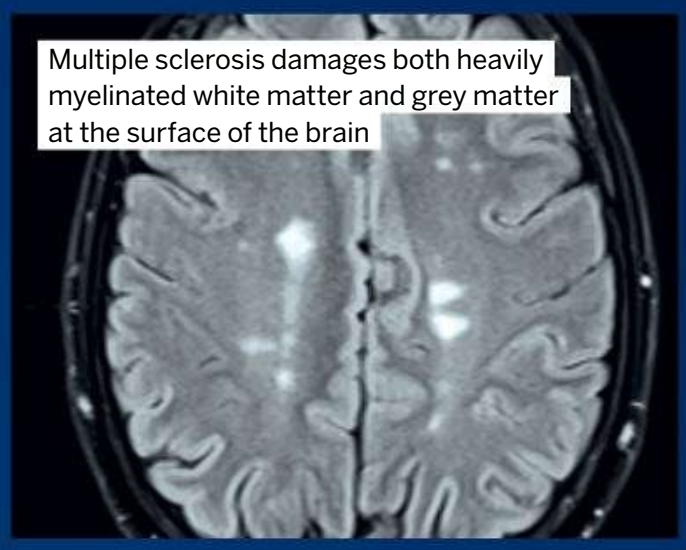
DAMAGED MYELIN
In multiple sclerosis, the immune system causes inflammation that destroys myelin and the cells that produce it.

EXPOSED NERVE FIBRE
Without myelin, nerves are vulnerable to inflammation damage, which causes scarring, and are less able to conduct nerve signals.

MYELIN SHEAF
Myelin is a material composed of fats and proteins that coats healthy axons, protecting them and speeding up nerve transmissions.

Did you know?

Many neurons cannot be renewed if they're damaged



Multiple sclerosis damages both heavily myelinated white matter and grey matter at the surface of the brain

Research is in progress to use virtual reality as a diagnostic tool for neurological disorders

Peripheral neuropathy from diabetes can result in a loss of sensation in the feet

PERIPHERAL NEUROPATHY

While several degenerative disorders primarily or exclusively impact the central nervous system, there are a collection of diseases that instead impact the peripheral nervous system, called peripheral neuropathies. As the impacted region is the peripheral nervous system, such neuropathies lead to a loss of sensation and regulatory control of extremities. These include a loss of coordination and feeling in fingers and toes and a lack of balance. The causes of peripheral neuropathy are yet to be fully made clear, but scientists have determined diabetes, which causes protracted periods of high blood sugar, as one of the primary causes.

Early symptoms of Parkinson's include tremors in the hands

PARKINSON'S

The basal ganglia are found deep within the brain, in an area responsible for controlling movement. These nerves produce a compound known as dopamine, which is important in coordinating numerous functions, including executive functions and motor control. Although the cause is not yet clear, the basal ganglia can become impaired and begin to die. The result of this is Parkinson's disease, as the loss of dopamine gradually hampers key functions such as walking, talking and memory recall. These effects are compounded by the loss of nerves responsible for producing norepinephrine, a key compound in the sympathetic nervous system needed to regulate heart rate and blood pressure.

© Getty / Alamy

SPECIAL

THE NERVOUS SYSTEM BY NUMBERS

1,000

Our smallest neurons have cell bodies 1,000 times smaller than a grain of rice

WHEN YOU KNOCK YOUR 'FUNNY BONE', YOU'RE ACTUALLY PINCHING THE ULNAR NERVE

THE CENTRAL NERVOUS SYSTEM IS PROTECTED BY CEREBROSPINAL FLUID

The phrase 'nerves of steel' stems from an ancient misunderstanding about motor nerves

Electrical signals travel fastest through wide neurons with myelinated sheaves

Neurons in the peripheral nervous system are typically able to regenerate

500ML

On average, adults secrete half a litre of cerebrospinal fluid a day

MOST OF AN OCTOPUS' NEURONS ARE IN ITS ARMS

86 BILLION

The estimated number of neurons in the human brain

DID YOU KNOW? When Albert Einstein died, some doctors reasoned his brain's structure must be different, so they stole it

Purkinje cells are a type of neuron exclusively found in the cerebellum

MYELIN IS RESPONSIBLE FOR GIVING THE BRAIN'S WHITE MATTER ITS NAME

1700 BCE

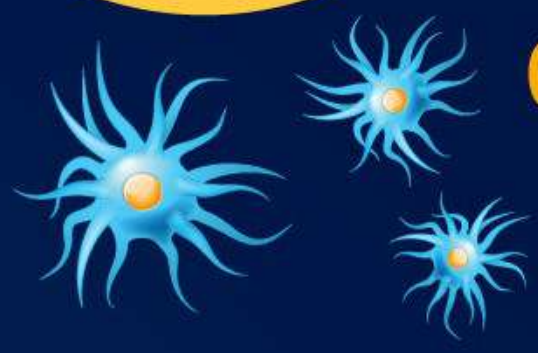
Medical documentation of the nervous system was first written nearly 4,000 years ago

100

Unmyelinated neurons send signals about 100 times more slowly than myelinated ones

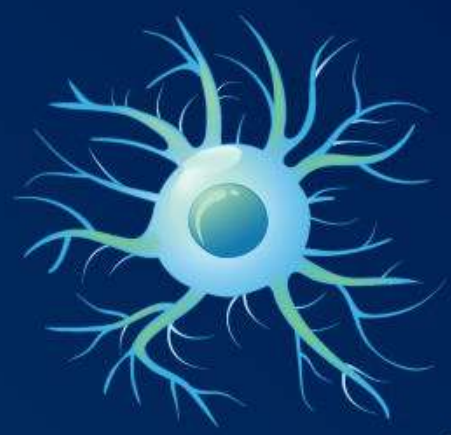
SATELLITE CELLS REGULATE THE CHEMICAL ENVIRONMENT AROUND SENSORY AND AUTONOMIC NEURONS

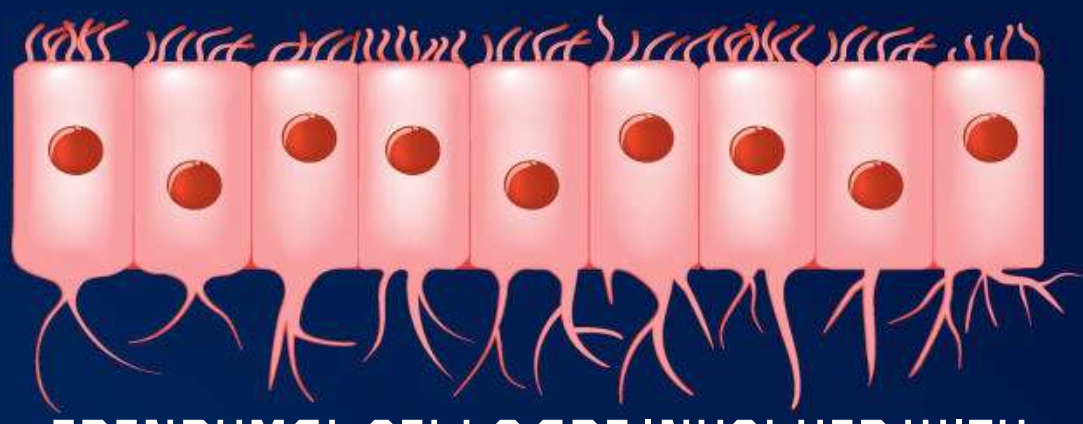
MICROGLIA ACT AS THE BRAIN'S IMMUNE CELLS AND DEFEND IT AGAINST DISEASE



Astrocytes control the levels of ions and neurotransmitters around synapses

SCHWANN CELLS COAT NEURONS IN THE PERIPHERAL NERVOUS SYSTEM WITH MYELIN





EPENDYMAL CELLS ARE INVOLVED WITH CREATING CEREBROSPINAL FLUID

1,336 GRAMS

An adult male's brain weighs as much as a young cat

Human intelligence is likely owed to neuron count and how our neurons are organised

©Getty

COLD SCIENCE

How low temperatures can change the state of elements and both injure and heal living tissue

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? The lowest body temperature an adult has survived is 13.7 degrees Celsius

When is something considered to be cold? There isn't a hard-and-fast rule that when something reaches a certain temperature it can be deemed cold. However, at the point where the temperature is closing in on the freezing point of water, it's safe to say it's pretty cold. Anything below zero degrees Celsius is known as sub-zero, and below sub-zero is where atoms and molecules start to truly become 'frozen'. Although countries around the world use either Celsius or Fahrenheit, the universally recognised measurement for temperature is known as Kelvin. This base unit was named after British physicist William Thomson, also known as Lord Kelvin, for his work in thermodynamics during the 19th century. The scale runs from the lowest theoretical temperature, known as absolute zero, up to the hottest known temperatures in the universe. Absolute zero occurs at zero Kelvin, equal to -273.15 degrees Celsius. Molecules at this starting point for temperature would have theoretically lost any kinetic energy – the energy associated with movement.

When atoms and molecules are hot, they're packed with kinetic energy, causing them to move around rapidly and even break apart. As you move the thermometer south, the opposite occurs and atomic movement decreases. As this energy decreases, the elements move through different stages of matter, from energetic gases to energy-lacking solids. For example, as hot water vapour cools, it condenses into a liquid and eventually forms ice at its freezing point. Of course, the physical state of a molecule or element doesn't instantly identify whether or not it's hot or cold. For example, one of the coldest known substances is liquid nitrogen. Different elements in the periodic table change states of matter at different temperatures. Nitrogen is an element that transforms from a solid to gas under extremely low temperatures. In its coldest solid state, nitrogen is below 63 Kelvin (-210 degrees Celsius), while at 77 Kelvin (-195.15 degrees Celsius) it becomes a liquid.

The effect of a cold temperature on molecules can be helpful, particularly when it comes to preserving our food. Freezing is one of the easiest ways to store perishables and prolong its edible life span. Within our food are enzymes that break them down over time. Stored in the cold temperatures produced by your fridge freezer, the ability of these enzymes is removed. Similarly, any microorganisms that are lurking in our food are halted when frozen, but are not killed, and may be revived when food is defrosted.

Cold can also harm the human body if it's exposed to low enough temperatures for long enough. Under normal conditions, the human body has a core temperature of around 37 degrees Celsius for optimal functioning of its tissue and organs. At the point that your core temperature drops below 35 degrees Celsius, your body will experience hypothermia. During hypothermia, the body will undergo several changes, such as shivering, changes in colour and shallower breathing in an attempt to conserve heat. In this case, medical attention is urgently needed. The ambient temperatures that can cause such reactions are not that low, between -1 and 10 degrees Celsius.

Cold isn't always harmful to the human body and it's commonly used as a form of treatment for several conditions, called cryotherapy. One of the uses of cryotherapy is in the treatment of different types of cancer. It's also known as cryosurgery and has been widely used in the treatment of certain benign and malignant bone tumours. In bone cancer patients, treatment often centres around the replacement of portions of bone with an artificial alternative, thus removing any cancerous tumours. However, freezing bone is also proving to be a successful substitute in some cases. Pedicle cryotherapy, a relatively new procedure, detaches and exposes a portion of cancerous bone located in the arms or legs and uses liquid nitrogen to remove tumours. The liquid nitrogen is poured over the exposed bone until it is frozen solid and induces tissue necrosis (death) by dehydrating body cells, along with cancerous cells, and forming ice crystals within them. Once the cells are dead and the bone is thawed, the bone is reinserted into the body and reattached at the broken end. Over the following months, the bone heals and new, healthy tissue regrows around it.

Did you know?

The first thermometer was invented in 1612

A vial of the soft, silvery-metallic element rubidium

REACHING ABSOLUTE ZERO

In 2021, scientists at the University of Bremen in Germany came the closest anyone has ever gotten to achieving absolute zero using a cloud of 100,000 rubidium atoms that were suspended in a magnetic field and cooled to around two-billionths of a degree Celsius. The experiment created what's known as a Bose-Einstein condensate, a mysterious state of matter where atoms hardly move, clump together and behave like a single atom. This ultracool cloud was held in a vacuum chamber that was then tossed off a 37-metre-tall tower. On its descent, the magnetic field in the vacuum chamber was switched on and off to send the Bose-Einstein condensate into a state of microgravity and reduce its temperature even further. For around two seconds, the scientists further cooled the condensate to about 38-billionths of a Kelvin.

FORMING ICE

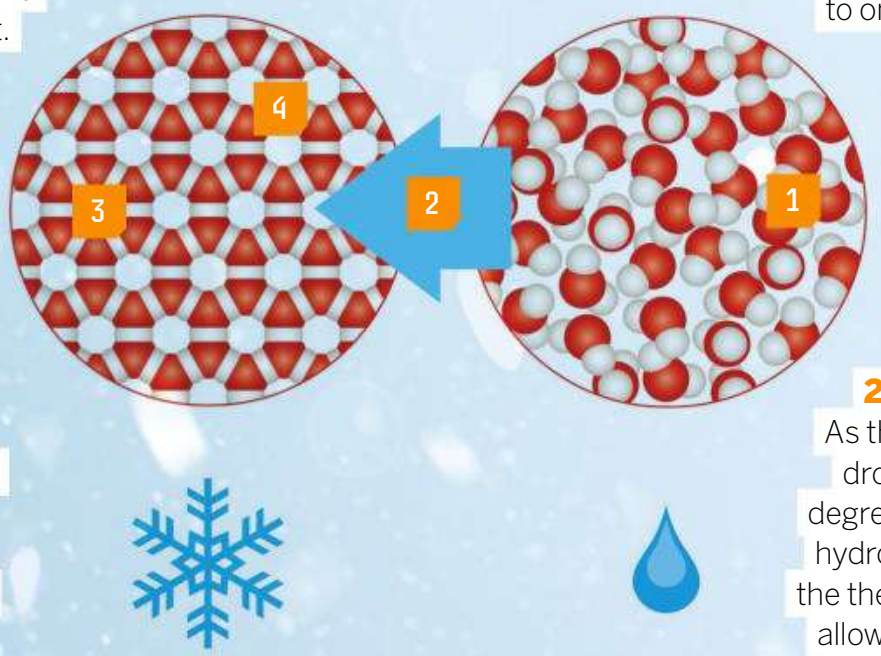
How the cold makes molecules get in line

1 LIQUID WATER
In its liquid state water consists of a network of hydrogen bonds where two hydrogen atoms are connected to one oxygen atom.

2 COOLING
As the temperature drops below four degrees Celsius these hydrogen bonds lose the thermal energy that allows them to move around more easily.

3 ICE FORMATION
Water's hydrogen bonds become stronger when cooled and form crystalline structures.

4 DENSITY
The crystalline structure of ice causes spaces between the bonds, making it less dense than water and allowing it to float.



© Getty / Alamy

COLD AND THE HUMAN BODY

The cold can harm the human body, but can also be its saviour

COLD RASH

Cold temperatures can draw moisture from the skin, leaving it feeling dry. In some extreme sub-zero temperatures, the skin can erupt in a rash called cold panniculitis. This rash commonly occurs on the cheeks and chin, which are usually exposed to the elements. It is especially common in children.

Did you know?

Heart attacks are more common in the winter

COMBATING CANCERS

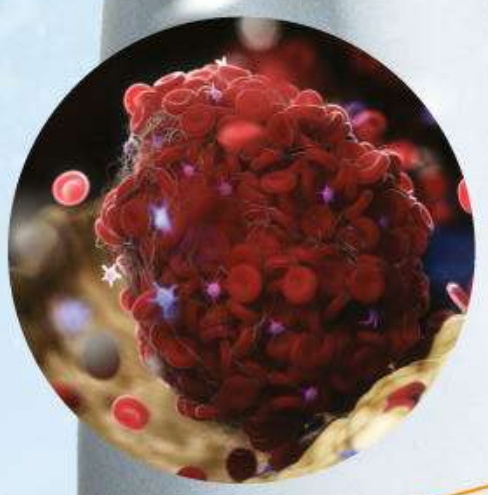
In a similar way to how liquid nitrogen is used to tackle surface skin warts, doctors use a surgical instrument called a cryoprobe that can deliver tiny amounts of liquid nitrogen to internal organs to treat some forms of cancer, such as cervical and liver cancers.

HEART ISSUES

Extreme cold weather can increase the risk of a heart attack. Blood is the body's natural heat source, designed to keep our vital organs warm. To regulate and sustain that internal heat, the heart works harder to increase the body's temperature, putting it under more strain.

FROSTBITE
When tissue – particularly cells at the extremities – is exposed to extreme cold temperatures, it can cause it to die. This is known as frostbite, where ice crystals form within the cells at the points of the body that receive the least amount of heat carried by blood, such as the fingers and toes. This can ultimately lead to tissue death and necessitate amputation.

FROZEN WARTS
Stubborn warts and verrucas can be treated with liquid nitrogen. Simply applying the chilling substance will cause the wart to freeze, cutting off its blood supply and causing it to come away from the skin over time.



THROMBOSIS
Thrombosis is the formation of blood clots, also called thrombi, that block veins and arteries. In cold conditions it can cause platelets in the blood to stick together more easily, which can increase the risk of thrombi forming.

© Getty / Alamy

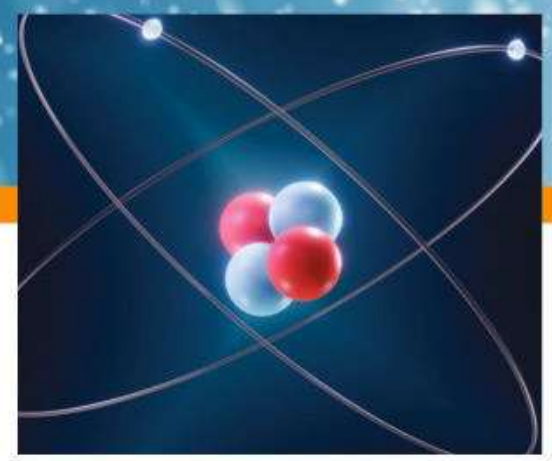
CHILLY CHAMPS

Here are some of the coldest record holders in existence

A tardigrade, also known as a water bear

THE COLDEST LIVING THING

Tardigrades are some of the strangest and toughest living creatures in existence. Also known as water bears or moss pigs, tardigrades are small invertebrates that measure around 0.05 to 1.2 millimetres in length. One of the things that makes them unique is their ability to survive in the most extreme conditions – they can be found in almost every habitat on Earth. Researchers have discovered that these hardy creatures can survive at temperatures as low as -200 degrees Celsius. Tardigrades do this by entering into a death-like state known as cryptobiosis. While in this state, they expel more than 95 per cent of the water in their bodies. Their bodies are then protected by proteins that form a glass-like cocoon around each of their cells. Tardigrades can also revive themselves, even after decades of cryptobiosis slumber.



A conceptual illustration of a helium atom

THE COLDEST MELTING POINT

Helium takes the crown for the element with the lowest melting point in the known universe at a freezing -272.2 degrees Celsius, which is only a 0.95-degree separation from absolute zero. The melting point of an element is the energy required to transform a substance from a solid into a liquid. Helium gets its low melting point from its weak intermolecular forces and the small amount of interaction that occurs between each atom of helium. This means that it can be used as a cooling medium for particle accelerators and superconducting magnets.

Another snowy day in the village of Oymyakon, Russia

EARTH'S COLDEST POPULATION

A remote village in eastern Siberia called Oymyakon is the coldest permanently inhabited place on Earth. The lowest recorded temperature in the village is -67.7 degrees Celsius. The region is an area of permafrost, which means that the ground is at a constant zero degrees Celsius. This also means that not much can grow on the frozen ground, so the diet of Oymyakon residents consists mainly of meat and fish. Due to freezing temperatures, indoor plumbing is nonexistent in Oymyakon, and all bodily waste is expelled in chilly outhouses. Oymyakon takes its name from the Russian for 'water that doesn't freeze'.

DID YOU KNOW? The lowest temperature recorded on Earth was -89 degrees Celsius at Vostok Research Station, Antarctica

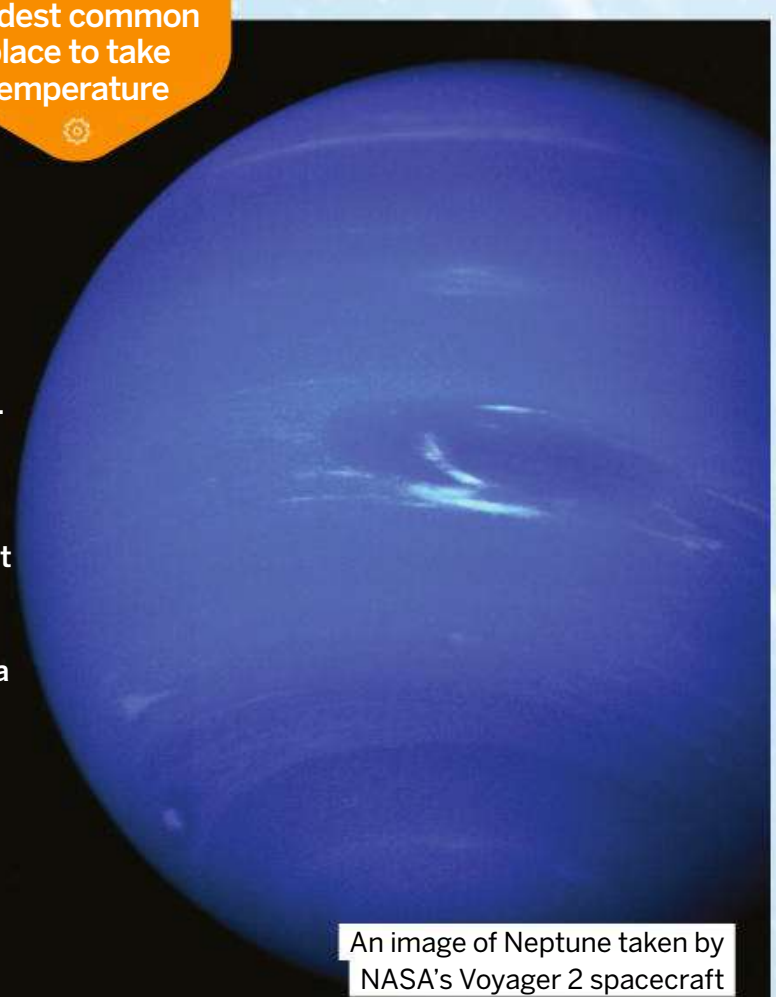
An image of the Boomerang Nebula taken by the Hubble Space Telescope

COLDEST PLANET

Neptune is an ice giant and is considered the coldest planet in the Solar System, with a surface temperature of -200 degrees Celsius. The previous holder of this title was Pluto, which has a surface temperature of -225 degrees Celsius, but it was demoted to a dwarf planet in 2006. The main reason that Neptune is so cold is because of its distance from the Sun. As the most distant known planet in our Solar System, it receives the least amount of heat from the Sun's rays. Neptune's atmosphere is made of hydrogen, helium and a little methane, which can maintain a gas state under the planet's freezing temperatures. Even though the methane present in Neptune's atmosphere acts as an insulating blanket, as it does on Earth, the trace amounts mean Neptune can't stay as warm as the methane-abundant Uranus, at -195 degrees Celsius.

Did you know?

Armpits are the coldest common place to take temperature



An image of Neptune taken by NASA's Voyager 2 spacecraft

THE UNIVERSE'S COLD SPOT

Beyond the frozen poles of Earth, the universe has countless regions of unimaginable coldness. However, there's one place that's colder than anywhere else in the cosmos: the Boomerang Nebula. This protoplanetary nebula sits around 5,000 light years from Earth and is made of clouds of gas and cosmic dust. It was discovered in 1995, and astronomers measured its temperature at only a degree above absolute zero (-272 degrees Celsius). Its chilly disposition is thought to be the result of a star throwing itself into the heart of a larger red giant star.

Normally planetary nebulae are created when a single star dies and explodes in a supernova event. During this process, the core of the star collapses under the gravity of the universe, causing gas and other cosmic matter to rapidly expand outwards into space. When gas molecules are released from the pressure created by a star's nuclear centre and expand rapidly, they slow down and exert less thermal energy. The faster a gas expands, the slower the individual molecules move and the colder they become. The gases emitted from the collision at the heart of the Boomerang Nebula are expanding ten times faster than the gases emitted from the supernova of a single star, at around 93 miles per second, which scientists believe is the cause of its ultracool nature. The astronomers that discovered it used a ground-based telescope in Australia, revealing a curved boomerang shape. However, Hubble images have since revealed the nebula is more like a bow tie than a boomerang.

© Getty / European Space Agency, NASA / NASA/JPL

BATTERY BASICS

How do these portable power sources store and release electricity?

WORDS LAURA MEARS

DID YOU KNOW? You can charge your phone between 200 and 300 times before its battery capacity starts to drop

Batteries are pocket reactors. They generate electricity using chemicals that release currents of electrons. These subatomic particles have a negative charge. When they travel from place to place, they take that charge with them, providing the energy to power our devices. Batteries work because of three basic principles: first, that electrons in metals can move around. Second, that particles with positive or negative charges can move freely when they dissolve in liquids like water. And third, that when you put two different metals together with a liquid containing charged particles, one metal can take electrons from the other.

It took humanity thousands of years to put these principles together to create batteries as we know them. But our ancestors did manage to create something like a battery long before the science of electricity really took off. In fact, the very first example predates the Colosseum. Known as a Parthian galvanic cell or a Baghdad Battery, it was about the size of a football. On the outside it looked like a normal clay pot, but inside it held an iron rod, a copper cylinder and an acid like vinegar or wine. Acids contain dissolved ions, allowing the iron and the copper to exchange electrons. Science historians think that these ancient batteries would only have been able to generate a very small voltage. But these early cells laid the foundations for a revolution thousands of years in the future.

In the late-1700s, just after Benjamin Franklin flew a kite in a storm, Alessandro Volta was travelling through Europe. He noticed another scientist, Luigi Galvani, experimenting with electricity in frogs' legs. When Galvani hung the legs from brass hooks and touched them with an iron scalpel, they twitched. He had come to the conclusion that there must be some kind of 'animal electricity' inside the frogs, but Volta disagreed. He noticed that Galvani was using two different types of metal, and he thought that this might be the key. To prove this, Volta set about recreating the experiment without the frog. He stacked slices of zinc and copper and replaced the frogs' legs with cloth soaked in salt water – this mimicked the salty liquid inside animal tissue. Sure enough, his contraption generated a current.

When two different metals are connected by an electrolyte – a liquid containing dissolved ions – they undergo a redox reaction. It has two parts: the 'red' stands for reduction and the 'ox' for oxidation. In Volta's battery, the surfaces of the zinc plates oxidised, releasing positively charged zinc ions into the water and leaving electrons behind. Meanwhile, the surfaces of the copper plates reduced, passing electrons to ions in the water. To balance everything out, electrons had to travel from the zinc to the copper through a wire, and that's what created the current.

Since then, battery chemistry has continued to evolve. In 1859, Gaston Planté unveiled the first rechargeable battery. And in the 1980s, three Nobel Prize winners invented the lithium-ion battery. It was so revolutionary that its descendants now power almost everything portable, from your mobile phone to the International Space Station.

Volta called his battery the 'electric organ'. It's now known as a voltaic pile

HOW BATTERIES WORK

All batteries have the same basic components: two electrodes and an electrolyte

ANODE
The negative electrode releases electrons into the circuit.

MAKING ELECTRONS
The anode oxidises, releasing positively charged ions into the electrolyte.

ELECTRODES
All batteries need somewhere for electrons to come from and somewhere for electrons to go.

CATHODE
The positive electrode takes electrons from the circuit.

TAKING ELECTRONS
The cathode reduces, giving electrons to positively charged ions in the electrolyte.

ELECTROLYTE
The electrolyte allows ions to move between the anode and cathode.

© Getty / Alamy / Wiki: Luigi Chiesa

MODERN BATTERIES

There are dozens of different kinds of batteries. Perhaps the most familiar are the single-use alkaline batteries found in toys, torches and remote controls. They get their name from their electrolyte, potassium hydroxide. They are small, efficient and have a long shelf life, but they don't pack much power. At the other end of the scale are the industrial batteries at solar farms. Known as grid-scale batteries, they're capable of storing and releasing enough energy to power thousands of homes. The largest, currently under construction in Australia, is set to provide storage of 1,200 megawatts.

Similar to the batteries found in your phone or laptop, grid-scale batteries work by shuttling positively charged lithium ions. They can be recharged hundreds of times, they hold lots of energy for their size and they don't go flat when you leave them idle – unlike the lead acid battery in your car. But they're not the best batteries on the market. That title goes to air batteries. Expensive and still somewhat experimental, air batteries have the potential to revolutionise portable energy once again. They use oxygen to release electrons, making them much lighter than their conventional counterparts.

The lithium-ion batteries in phones are some of the most advanced

Did you know?

The UK throws away 600 million batteries a year

If you don't use a car battery for two weeks it can go flat

"Air batteries have the potential to revolutionise portable energy"

RECHARGEABLE OR DISPOSABLE

Batteries run out of power when the chemical reactions inside them stop. The anode no longer releases ions, and the cathode no longer wants to take them. But that's not always the end. Some types of battery let you run the reactions in reverse. If you connect them up to a power source, you can force the ions back. The electrolyte returns positive ions to the anode, and the cathode lets go of the negative ions it has collected. This makes it possible to use the battery again. However, this reversal isn't perfect. Electrodes start out as neat stacks of crystals, but when they discharge and recharge they become untidy. This affects their ability to store power in the future.

TESTING POWER

The test strips on batteries have three layers of ink. On top there's a heat-reactive ink that turns from black to clear when it gets warm. In the middle there's a coloured ink and on the bottom there's conductive ink that gets hot when a current passes through. That bottom layer is thinner at one end than the other, which means that it only gets hot when the current is high. When the battery is full, it generates enough electricity to reveal the whole test strip. As it starts to empty, less of the bar shows through.

Battery test strips use conductive and heat-reactive inks

Recycling plants break batteries apart so that the chemicals inside can be reused

DID YOU KNOW? Batteries in landfill leak dangerous chemicals like lead, cadmium and lithium into the ground

INSIDE A RECHARGEABLE BATTERY

Peel back the layers of a lithium-ion battery to find out how phones store charge

1 ANODE
At the negative electrode, graphite lets go of positively charged lithium ions and electrons.

2 CATHODE
At the positive electrode, lithium ions combine with cobalt oxide to make lithium cobalt oxide.

3 ELECTROLYTE
Lithium ions move between the electrodes across a polymer layer called a separator.

4 NEGATIVE TERMINAL
The steel outer case of the battery connects the anodes to the circuit.

5 POSITIVE TERMINAL
The top cap of the battery connects the cathodes to the circuit.

SAFETY FIRST

Have you ever seen a crusty, white powder on a battery? Don't touch it; it's a chemical leak. The reactions inside standard batteries create hydrogen, a gas. Over time this gas can build up, causing the pressure inside the battery to rise. Then, pop! The outer casing bursts. Potassium hydroxide leaks out of the battery and reacts with carbon dioxide in the air to form potassium carbonate. This is the crusty white stuff, which looks a bit like salt. Potassium carbonate isn't dangerous to touch, but potassium hydroxide can burn your skin. Always take care when disposing of leaky batteries.

Batteries can leak their chemical contents when they get old

© Getty / Alamy / Duracell

HOW BLEACH KILLS GERMS

This cleaning cupboard staple tears through proteins, destroying bacteria and viruses in minutes

WORDS **LAURA MEARS**

Bleach kills harmful bacteria and viruses on surfaces

Household bleach is a bactericide; it kills bacteria on contact. It's one of the cheapest and most powerful microbe busters on the planet. But how does it work? The bleach under your sink is a solution of sodium hypochlorite, which has the chemical formula NaClO. That means that each molecule contains one sodium atom, one chlorine atom and one oxygen atom. In water it produces hypochlorous acid (HOCl), which can steal electrons from other molecules. It uses this ability to attack bacteria and viruses, breaking their proteins apart and splitting them open.

Hypochlorous acid also damages pigment molecules, turning them white, which is where bleach gets its name from. In its pure form, bleach is extremely corrosive. It has a pH of 13, making it just about as alkaline as you can get. Luckily, the bottle under your sink also contains water, lowering the pH to a slightly safer 11.

It doesn't take much bleach to completely sterilise a surface. Your bottle at home is only five per cent bleach, and you need to dilute it even further before you can use it safely. You only need 15 millilitres in 3.8 litres of water to sterilise a table that has been in contact with dirty water. To kill mould, you need a bit more – 240 millilitres in 3.8 litres. Bleach is so reactive that you have to use it within 24 hours of mixing it up or it won't be nearly as effective. It breaks down rapidly into salt and water, especially if it's warm, making it a much less powerful microbe killer. To keep it working at its best, store it in a cool, dark cupboard and only dilute just as much as you need to get the job done.

Did you know?

In 1785, Claude Louis Berthollet first used bleach on fabrics

It takes between 10 and 60 minutes for bleach to kill germs

Gloves can protect your hands against the damaging effects of bleach

CAN BLEACH BURN YOUR SKIN?

Yes. Bleach is toxic. It reacts with the surfaces it touches and takes their electrons in a chemical exchange called oxidation. This can damage your skin on contact. Bleach can also react with other household cleaners to create different and more dangerous chemicals. If you accidentally mix it with acid, it can produce chlorine gas. When this gas comes into contact with water – like the water in your eyes, nose or throat – it makes hydrochloric acid. This can cause chemical burns. That's why you should always wear gloves, make sure your area is well ventilated and never mix cleaning chemicals together.

DID YOU KNOW? In the UK alone, there are more than 3,000 bleach-related accidents requiring hospital treatment every year

HOW IS BLEACH MADE?

Bleach is an industrial chemical, and it's produced on an industrial scale. It involves two methods: the chlor-alkali process and the Hooker process. The chlor-alkali process produces the raw materials for bleach production: sodium hydroxide, also known as caustic soda or lye, and chlorine gas. It begins with salty water, also known as brine. The chlor-alkali process uses a technique called electrolysis to break the chemicals in brine apart and remake them into something new. When a current passes through the liquid, it turns water (H_2O) and salt (NaCl) into sodium hydroxide (NaOH), chlorine (Cl_2) and hydrogen (H_2). Two of these three ingredients go on to the next stage, the Hooker process. In the Hooker process, the sodium hydroxide is cooled and the chlorine gas is bubbled through. This produces NaClO, also known as sodium hypochlorite, the active ingredient in household bleach.

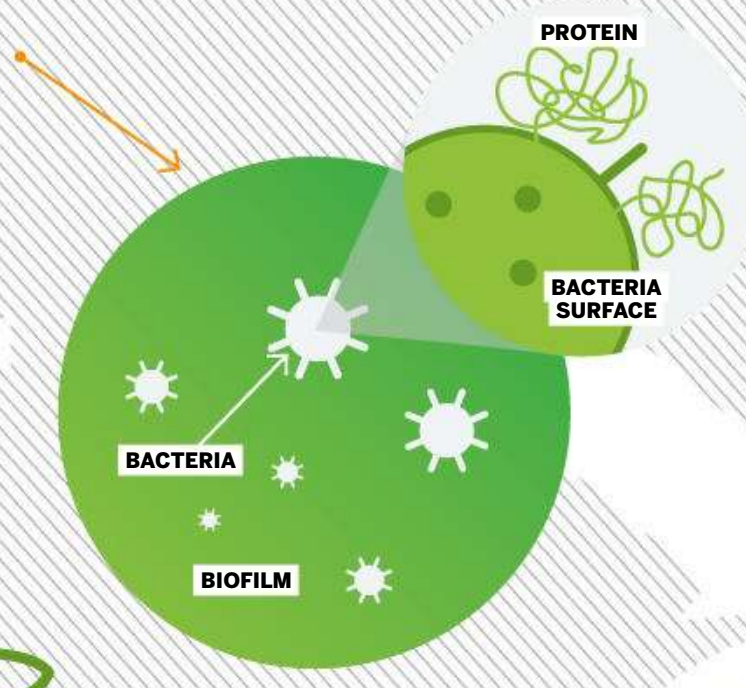
Bleach is made from chlorine gas and sodium hydroxide

HOW BLEACH KILLS

Using bleach is a great way to destroy bacteria

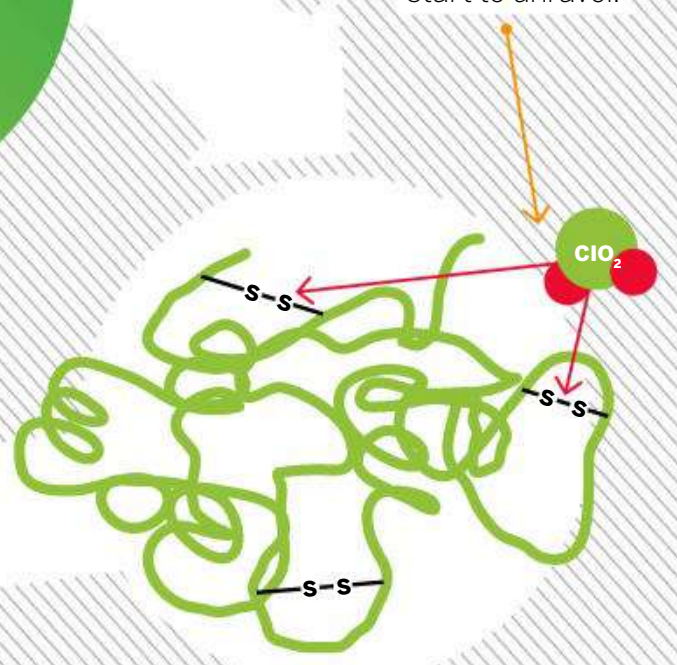
SURFACE PROTEINS

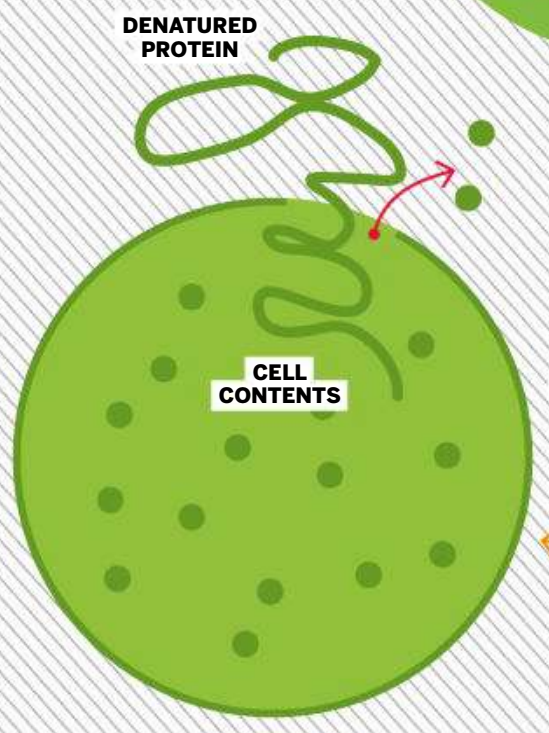
Bacteria contain lots of molecules called proteins. They work like molecular machines. These 3D structures have specific shapes that allow them to do jobs like take in nutrients or pump out waste.



BREAKING BONDS

Bleach attacks proteins. It forms an aggressive molecule called hypochlorous acid, which breaks the bonds that hold the 3D shapes together. As a result, the molecules start to unravel.





COMING UNDONE

The insides of proteins are sticky. When they unravel, they start to clump together like cooked egg. Without working proteins, bacteria can't survive.

"It doesn't take much bleach to completely sterilise a surface"

5 MYTHS ABOUT BLEACH BUSTED

1 MORE IS BETTER
Bleach is a powerful and dangerous chemical, so more is definitely not better. It only takes one tablespoonful in a gallon of water to kill germs.

2 IT CAUSES CANCER
While bleach can damage cells and can harm the lungs after long-term exposure, there's no evidence that it can cause cancer in humans.

3 IT CONTAINS CHLORINE GAS
Bleach contains the chemical sodium hypochlorite, which contains the element chlorine. But the bottle doesn't contain any free chlorine gas.

4 IT CREATES DIOXINS
Dioxins are toxic ring-shaped chemicals that cause health problems in humans. They're made during the industrial bleaching of paper, but they're not made by household bleach.

5 DRINKING IT KILLS CORONAVIRUS
Bleach can kill the SARS-CoV-2 coronavirus on surfaces, but it doesn't work on or inside the body. It causes serious harm to human cells.

©Getty

THE GOLDILOCKS ZONE

Journey into a star's habitable zone, where planetary temperatures allow liquid water to exist

WORDS **ANDREW MAY**

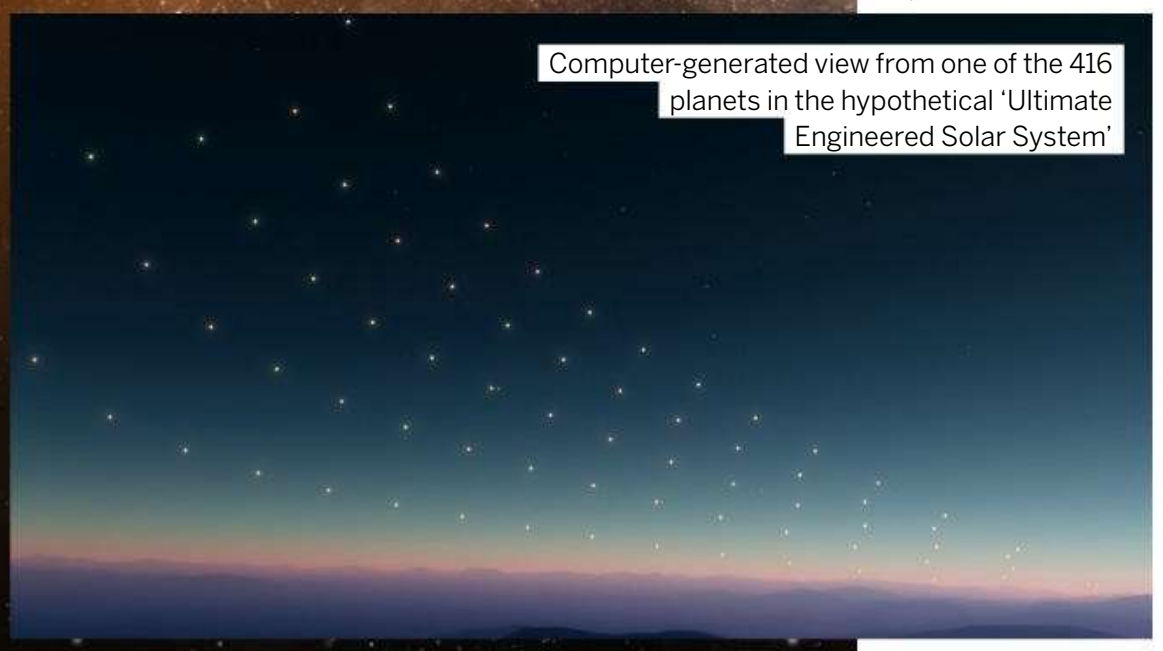
DID YOU KNOW? Special conditions, such as Europa's subsurface ocean, can allow water to exist outside the habitable zone

In the fairy tale, Goldilocks is a fussy little girl whose porridge has to be just right, neither too hot nor too cold. It's the same with life itself – or at least the kind of water-based life we're familiar with on Earth. A planet has to be just right: neither so cold that water only exists as frozen ice, nor so hot that it all boils away. That's not going to be true of all the planets orbiting a star, just those within a certain range of orbits dubbed the 'Goldilocks zone', or more formally the 'habitable zone'. If a planet's orbit takes it too close to its parent star then it will be too hot for liquid water to exist, and if it's too far out it will be too cold. That's obvious enough, but the actual distances involved, which define the boundaries of the habitable zone, will vary from star to star.

Our Sun is a G-type yellow dwarf, and there's no doubt where its habitable zone lies because Earth – orbiting around 93 million miles away – is within it. But for M-type red dwarfs, which are smaller and cooler than the Sun, the habitable zone lies much closer to the star. And for a larger, hotter, A-type star like Sirius, the Goldilocks zone is further out.

For astrobiologists, the people who search for life on other planets, being in the habitable zone is just one of the factors they have to think about. Take our Moon, for example. It obviously lies in the Goldilocks zone because it's so close to Earth, yet there's no liquid water on its surface. That's because atmospheric pressure and composition also have to be taken into account. This makes the Moon, which has no atmosphere to speak of, a non-starter. It's also important not to read too much into the word 'habitable'. Even if conditions on a planet are exactly right for the existence of liquid water, this doesn't necessarily mean it's inhabited. Scientists haven't yet worked out exactly how life first arose here on Earth, so we don't know what other subtle ingredients are necessary in addition to water and an atmosphere.

Our own Solar System is the best studied of all planetary systems. Theoreticians have worked out where its Goldilocks zone ought to be by estimating the surface temperature of a planet based on the amount of solar heating it receives. Reassuringly, the results agree with what we know from observations. The Earth – a very watery planet that's teeming with life – is situated comfortably inside the habitable zone. Mars, which seems to have had plenty of water in the past but is a barren desert today, is right on its outer edge. And at the inner edge is Venus – a boiling-hot planet thanks to both its proximity to the Sun and its super-thick atmosphere.



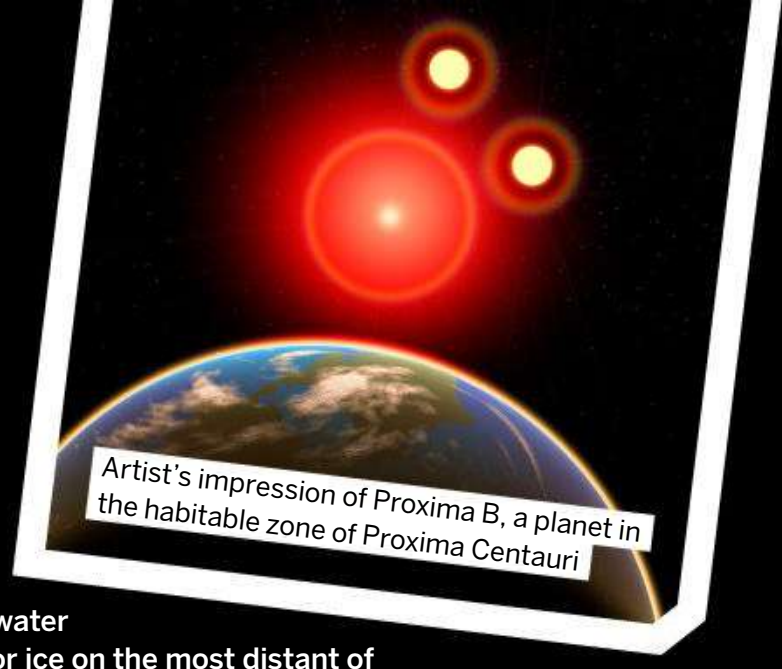
Computer-generated view from one of the 416 planets in the hypothetical 'Ultimate Engineered Solar System'

© Space Engine

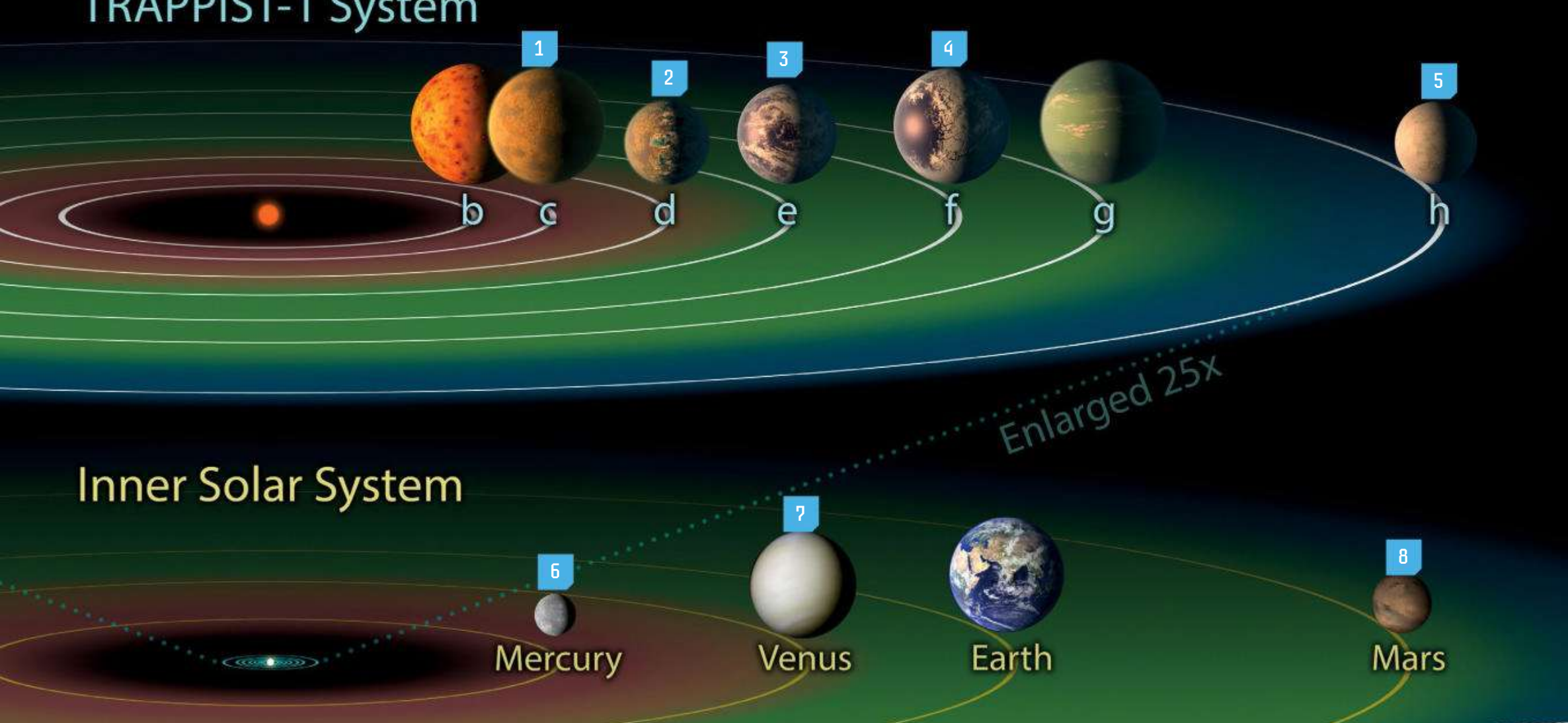
EXOPLANETS IN THE GOLDILOCKS ZONE

The discovery of new exoplanets orbiting distant stars has become almost commonplace. But it's always exciting when one is found within its parent star's Goldilocks zone. That happened in 2016 in the case of Proxima b, which orbits the Sun's nearest neighbour in space, red dwarf Proxima Centauri, just over four light years away. This star is so small and dim that its habitable zone is located at very close range, but Proxima B, which whizzes around the star once every 11 days, is safely inside it.

Another much-studied red dwarf is TRAPPIST-1. At around 40 light years away, it's farther than Proxima Centauri, but still a close neighbour in cosmic terms. TRAPPIST-1 is remarkable in having seven known rocky planets, three of them lying within the star's Goldilocks zone. It's possible that water is present on all seven planets, though only in a liquid state on the three inside the habitable zone. It would take the form of atmospheric water vapour on planets closer to the star or ice on the most distant of them. Astronomers are understandably keen to learn more about the TRAPPIST-1 system, and it's one of the planned targets for the James Webb Space Telescope.



Artist's impression of Proxima B, a planet in the habitable zone of Proxima Centauri



Did you know?

Around 60 habitable-zone planets are known to date

THE ULTIMATE ENGINEERED SOLAR SYSTEM

When a solar system forms, there's no reason planets should preferentially occur in the habitable zone, and the TRAPPIST-1 system is unusual in having as many as three planets there. But from a theoretical perspective, is there an upper limit to how many planets can be squeezed into the Goldilocks zone? That's a question that astrophysicist Sean Raymond addressed on his blog a few years ago. It turns out there is indeed a theoretical limit, beyond which the system becomes unstable because the planets are too close together.

Raymond came up with what he calls the 'Ultimate Engineered Solar System', with a grand total of 412 planets in the habitable zone arranged around eight concentric orbits that rotate in alternately prograde and retrograde directions.

DID YOU KNOW? The entire TRAPPIST-1 system would fit inside the orbit of Mercury, the Solar System's innermost planet

TWO HABITABLE SYSTEMS

TRAPPIST-1 and the Solar System have much in common, but are still quite different systems

1 TRAPPIST-1C
Too close to the star to be habitable, this planet may have a thick, swelteringly hot atmosphere like Venus.

2 TRAPPIST-1D
Around 40 per cent farther out than TRAPPIST-1c, this is probably still a little short of the habitable zone.

3 TRAPPIST-1E
This is the innermost planet in TRAPPIST-1's habitable zone and the one most likely to have Earthlike surface conditions.

4 TRAPPIST-1F
Right in the middle of the habitable zone, depending on its atmosphere this planet may have a lot of water.

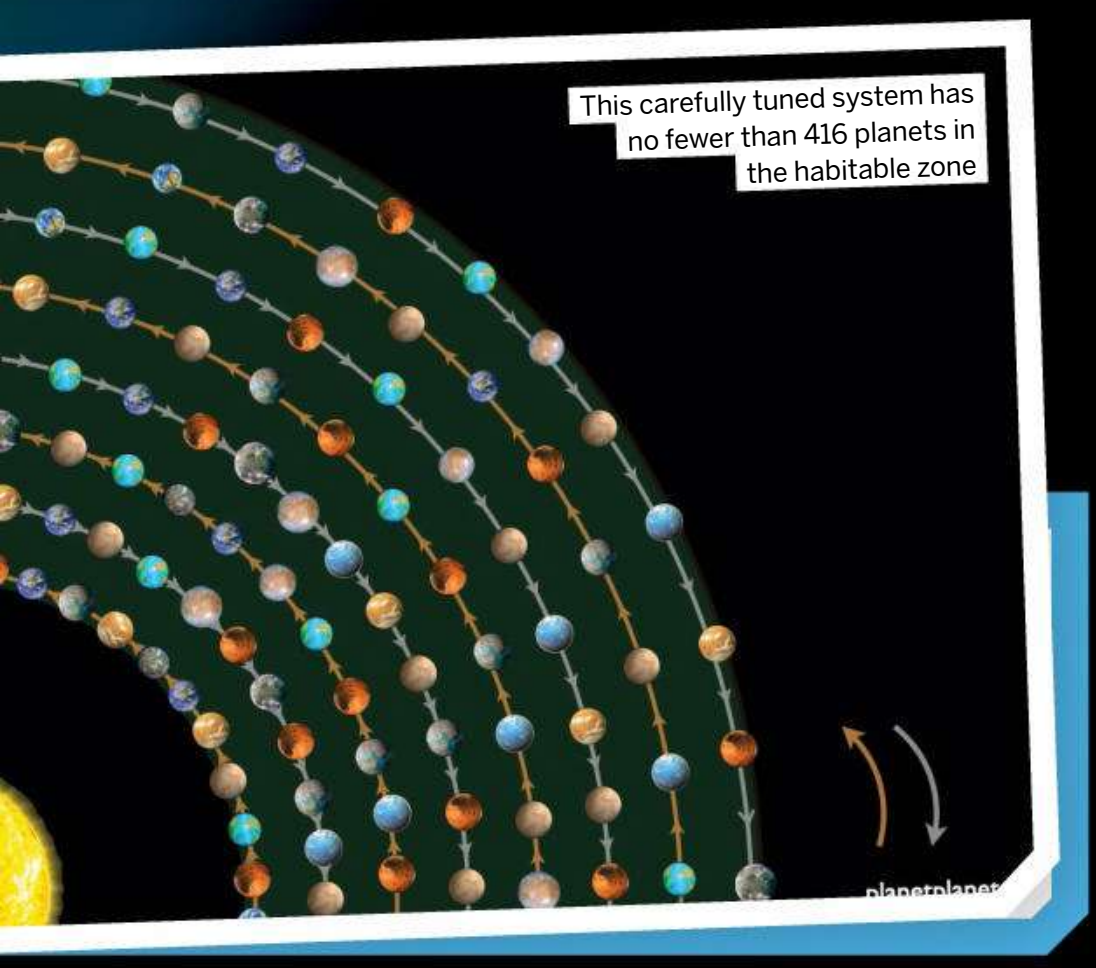
5 TRAPPIST-1H
The outermost of the known TRAPPIST-1 planets, this lies beyond the habitable zone and may resemble Saturn's icy moon Titan.

6 MERCURY
Estimates differ for the inner edge of the habitable zone, but they all lie well outside the orbit of Mercury.

7 VENUS
At 72 per cent of Earth's distance from the Sun, Venus is close to the Goldilocks zone's inner boundary.

8 MARS
Estimates for the outer edge also differ; depending which you use, Mars is just inside or outside the habitable zone.

"I tested the craziest systems using computer simulations"



Raymond writes about the interface of science and fiction at **planetplanet.net**

BUILDING THEORETICAL SOLAR SYSTEMS

We speak to Sean Raymond, originator of the 'Ultimate Engineered Solar System', about his work

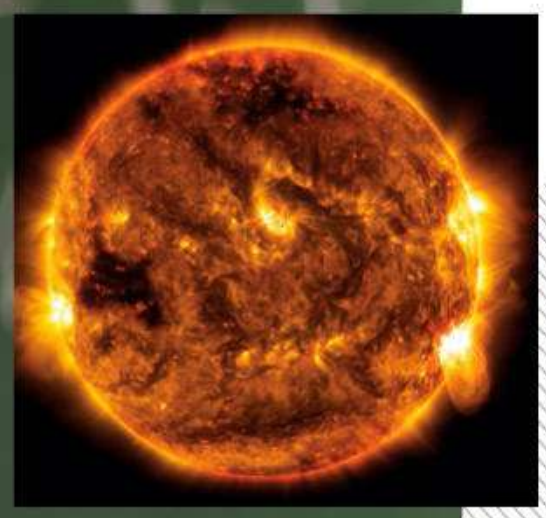
How did you come to create such a strange arrangement of planets?
My day job is to understand how planetary systems form, what makes the Solar System different from exoplanet systems that we've discovered, and what types of orbital configurations are stable and which aren't. I wanted to figure out what type of orbital architecture would maximise the number of planets in the habitable zone – remaining stable but without having to worry about how the system would have formed. Luckily, I could use several recent papers by scientists as inspiration. I also tested the craziest systems using computer simulations to make sure everything held together.

Why do you call it the Ultimate 'Engineered' Solar System?
Originally I built two systems, each with about 30 planets in the habitable zone. Those systems could plausibly form in nature if just the right series of events took place – like rolling sixes on two dice ten times in a row. But I can't imagine how the Ultimate Engineered Solar System could form naturally. A system with equally spaced planets distributed along rings orbiting in opposite directions is just impossible as far as I know. If such a system exists, I would argue that it must have been built on purpose, presumably by the engineers of a super-advanced civilisation.

If such a system really existed, how could we detect it from Earth?
It would be pretty tricky to detect because the signals we measure to infer the presence of exoplanets – typically the radial velocity or transit signals – could end up being so confusing that they might be mistaken for noise in the case of the Ultimate Engineered Solar System.

© Sean Raymond (planetplanet.net) / Getty

Šimkovic won the award for his work studying neutrinos



PROFESSOR FEDOR ŠIMKOVIC

At the bleeding edge of physics research, studying some of the smallest particles in the universe, professor Šimkovic's day-to-day work is stranger than you can imagine

INTERVIEWED BY **DAISY DOBRIJEVIC**

Nuclear and subnuclear physicist Šimkovic works at the Department of Nuclear Physics and Biophysics at Comenius University in Bratislava. He leads a team of young scientists and doctoral students in studying the fundamental properties of neutrinos – the most widespread elementary particles in the universe. His research covers various scientific fields of atomic physics, nuclear physics, particle physics and astrophysics. Šimkovic is an ESET Science Award laureate, winning the Outstanding Individual Contributor to Slovak Science award in 2020.

What are neutrinos?

Neutrinos are one of the most abundant fundamental particles in the universe. They come in three types, or flavours: electron neutrinos, muon neutrinos and tau neutrinos. A neutrino is similar to an electron but has no electrical charge and a tiny mass. Neutrinos are not part of an atom, unlike protons, neutrons and electrons. Like other constituents of the Standard Model of particle physics, they are assumed to be point-like objects – they aren't made of any smaller pieces that we know of. According to the Standard Model, there exist 12 fundamental particles, namely three families of leptons – electron, muon and tau and corresponding neutrinos – up quarks and down quarks and their antimatter versions. The

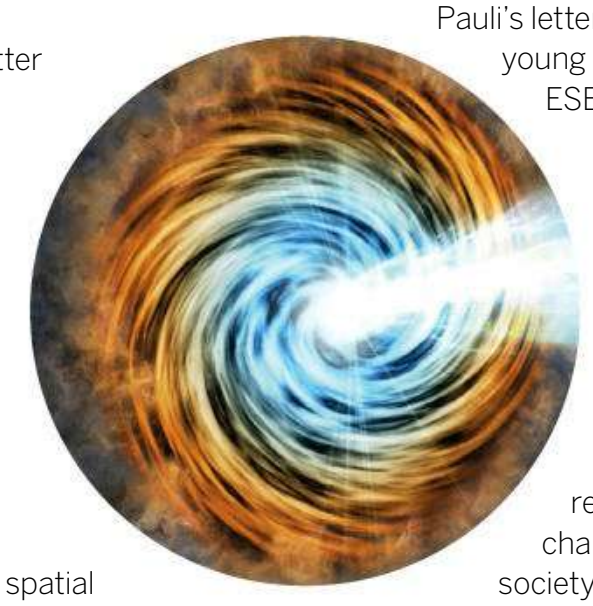
most abundant are neutrinos, created in the universe's first second just after the Big Bang. Theory predicts that there are 340 Big Bang neutrinos in every cubic centimetre in the universe. Due to very low energy, they've not been confirmed yet. They form a cosmic neutrino background with a very low temperature of about -271 degrees Celsius. Nowadays, neutrinos remain a mystery for physicists.

Why are neutrinos so difficult to detect?
They stream through most matter as light rays go through a transparent window. Billions of them pass through us every second – mostly coming from the Sun – though we won't feel it. We detect them only indirectly via different modes of weak interactions with matter, and these are easily detected. But again, the main problem is that these reactions happen only rarely. Neutrino detectors are primarily located deep underground or underwater to suppress background processes, mostly those with an origin in cosmic rays.

"Billions of them pass through us every second – mostly coming from the Sun – though we won't feel it"

What can studying neutrinos tell us about the universe?
Humankind has studied the universe for thousands of years by looking at the fascinating night sky full of stars and planets. Starting with the previous century, electromagnetic radiation of different wavelengths, such as radio waves, infrared light, X-rays and gamma rays, was exploited to open additional windows to the universe. Today scientists are starting to open a completely new window to the universe by means of neutrinos that deliver information about its make-up and the history of the stars and galaxies. This new field, called neutrino astronomy, will hopefully reveal new unknown phenomena and help us answer several of the questions we have today.

We don't know why in our universe, matter dominates over antimatter, which we practically do not observe. If the same amount of matter and antimatter had formed at the beginning of the Big Bang, they should have annihilated each other a long time ago and transformed into energy. We do not observe the processes of annihilation of matter and antimatter in the universe. If we want to make an omelette, we have to break an egg. If we want to create a world, we must break the symmetry. Due to hypothetical heavy neutrinos, disruption of charge and spatial symmetry may be responsible for the current balance of matter and antimatter.



What do you hope to achieve with your research?
Neutrino physics is exciting and full of thrilling discoveries. Neutrinos remain the most mysterious fundamental particles, and we still don't know the answers to several undeniably basic questions. I am a theorist interested in all the processes in which the neutrino is involved. For me, the atomic nucleus is a laboratory for studying the interactions and properties of neutrinos. It's amazing if experimental measurements confirm the theoretical assumptions. My life task is to organise and develop neutrino physics in Slovakia. I established a team of young physicists at Comenius University in Bratislava, working on problems of three prominent neutrino physics experiments. We are trying to unite the neutrino community and attract more young people to neutrino physics.

How does it feel to win the ESET Science Award for Outstanding Individual Contributor to Slovak Science?
Unrepeatable. Unforgettable. I've never experienced such a feeling, and I keep coming back to it. The moment when the chairman of the ESET Science Award International Jury – the Nobel Prize winner Kip Thorne – said my name is still in front of my eyes. The award symbolically came on the 90th anniversary of the first report about neutrinos in Wolfgang Pauli's letter to Tübingen. I will be very happy if my young coworkers or students will be awarded the ESET Science Award prize in the future.

Has your outlook on scientific research changed since winning?
Nothing has changed in my scientific plans. I believe that the award will help build our scientific team focused on neutrino physics, attracting more skilled young people to solve current theoretical and experimental tasks in neutrino physics research. The ESET Science Award has changed my view on the role of science in society and the need to contribute to making it better. Science is long-distance running, and its importance is not well understood. It often produces results that are not clear enough. But it turns out that the desired knowledge and outputs will come over time.

In order to become a country of knowledge, it is essential to prepare society for the significant changes that are sure to come. The labour market structure will be changed with the introductions of robotics, modern technologies, bioengineering and artificial intelligence. Climate change is approaching. In solving the related tasks and challenges, the potential for science is enormous.

In addition, we have to understand the universe itself and the processes inside it. It might be that neutrino physics will help us receive and identify signals from other civilisations. As Enrico Fermi said: "Where are the other Earths?" We are at the beginning of the road, and it's hard to predict where it goes.

Above: The ESET Science Award stands as a testament to Slovak scientific achievements and exceptional individuals

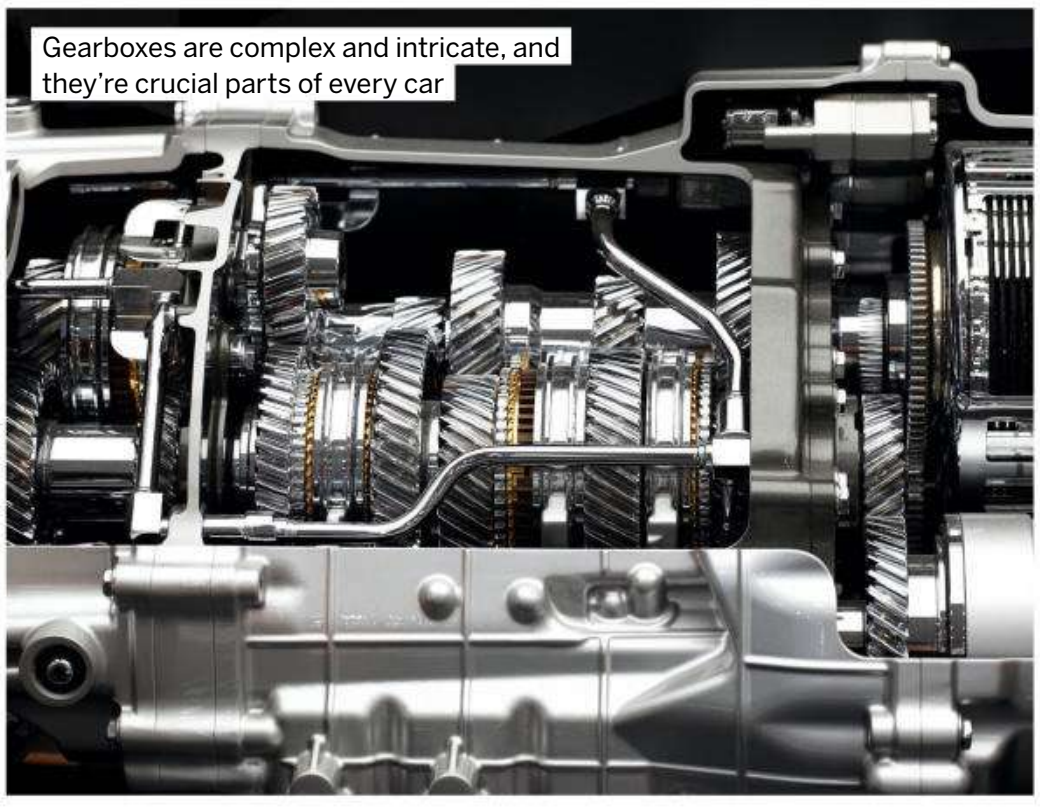
Inset circle: Blazars, associated with the supermassive black holes at the centres of active galaxies, are another confirmed source of extraterrestrial neutrinos

Opposite top: Low-energy neutrinos are produced in the Sun during nuclear fusion

Opposite bottom: Supernovae are a source of extraterrestrial neutrinos. In this image, SN 1987A was captured by Hubble within the Large Magellanic Cloud

© the photographer credit is Linda Kiskova Bohušová

© NASA/SDO/JPL-Caltech/GSFC / NASA, ESA, R. Kirshner (Harvard-Smithsonian Center for Astrophysics and Gordon and Betty Moore Foundation), and M. Mutchler and R. Avila (STScI) / ESET Science Award and the photo



Gearboxes are complex and intricate, and they're crucial parts of every car

Automatic gearboxes rely on hydraulic fluid, so they need to be topped up to keep them working well

INSIDE A CAR GEARBOX

Discover the secrets behind manual and automatic gears and their amazing history

WORDS **MIKE JENNINGS**

The gearbox is one of the building blocks of the modern car, and unsurprisingly it's also one of the most complex bits of hardware inside any vehicle. Despite all of that, the principle stays simple. A car's engine connects to its crankshaft, which rotates thousands of times per minute. That's too fast for the wheels, so gears convert the power to speeds the wheels can handle. They use interlocking teeth, connecting a small, fast-moving cog to a larger gear with more teeth, and that larger cog rotates at a reduced speed.

Lower gears have larger cogs, allowing the engine to deliver a lot of force without the car moving quickly, ideal when you're driving slowly or uphill. Higher gears deliver more speed rather than torque, which is great for smooth motorway driving. Lower gears deliver more power, while higher gears supply more speed – but you've got to shift your way up through the gears to reach those high speeds. Most cars have at least five gears, giving drivers finer control over power and speed.

Gearboxes have been around for a while: the first modern manual transmission was demonstrated by French inventors Louis François René Panhard and Émile Levassor in 1894, and Louis Renault improved upon the design in 1898. In 1928 Cadillac introduced a synchronised system to make gear changes smoother. Automatic gearboxes appeared commercially in the 1940s, and now they're just as popular as manual gearboxes.

Beneath all of this, gears remain an ancient concept. Their use has been discovered in 4th-century China and in ancient Greece, and the world's oldest working clock has been using gears to tell the time in Salisbury Cathedral since 1386. Gears might be old, but they've clearly stood the test of time, and they're still integral to every car you see on the road.

Did you know?

Metal gearboxes are smelted at over 700 degrees Celsius

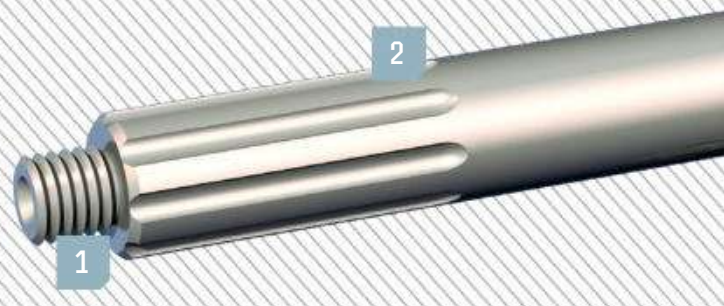
AUTOMATIC MAGIC

Automatic gearboxes are as popular as manual gearing in many countries, and they're far more prominent in the US. They're favoured because drivers don't have to mess around with clutch pedals and gear sticks. Most automatic cars use a torque converter system. Instead of using the clutch to separate the engine from the gearbox to change gears, the car relies on gearbox oil to transfer energy from the input shaft to the gears, and in turn the wheels. Computers determine exactly when gears need to be changed. This allows for smooth gear shifts and easier driving, and automatic gearboxes are often more efficient than their manual counterparts.

"Beneath all of this, gears remain an ancient concept"

2 CRAFTED SHAFTS

The input shaft rotates at the same speed as the engine and crankshaft; it delivers initial power to the gearbox.



1 CLUTCHING

The clutch decouples the engine from the gearbox, enabling gear changes – you can't change gear with parts rotating so quickly.

DID YOU KNOW? Automatic systems are so popular in the US that you can only buy a handful of cars with manual gearboxes

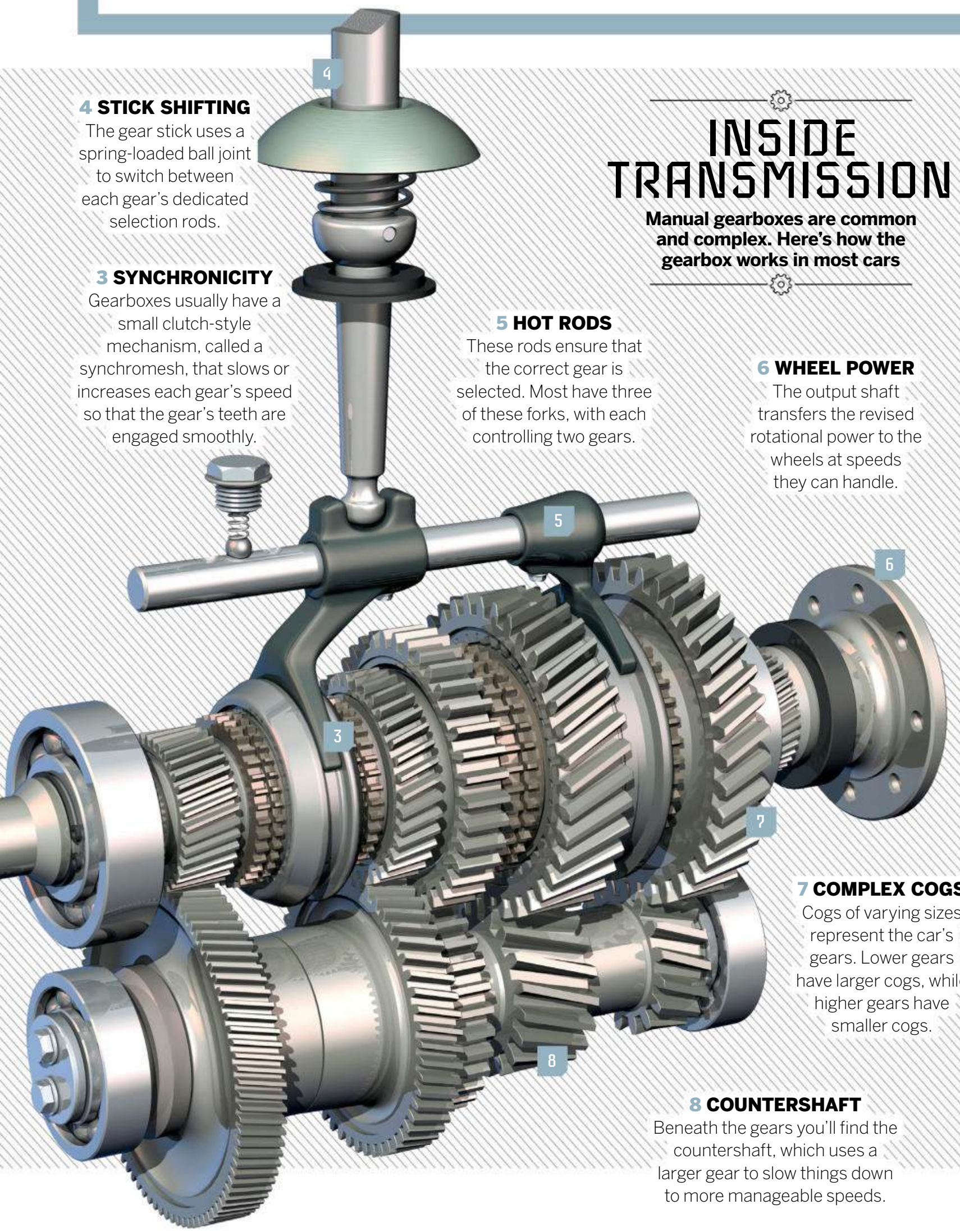
GEARING UP FOR THE FUTURE

Most cars still use manual or automatic gearboxes, but some new vehicles have modern continuously variable transmission (CVT) or dual-clutch systems. CVT is a type of automatic gearbox, but differs from conventional hardware in one key way. Instead of using normal gears, where drivers can feel the transitions, CVT gearboxes have a cone-shaped design and a system of pulleys to create a smooth transition up and down the car's power range. It's an efficient system that's often used in hybrids. Dual-clutch systems are often found in semi-automatic cars – the inclusion of two clutches means cars can preselect gears, which means you get incredibly quick gearshifts. You'll also find this system on high-performance cars and vehicles with gear-shifting paddles on the wheel. Manual gearboxes aren't immune from innovation either. Volkswagen has produced a new manual gearbox called the MQ281 that massively improves efficiency and reduces emissions.

Automatic gearboxes are often even more complex than conventional manual gear systems

INSIDE TRANSMISSION

Manual gearboxes are common and complex. Here's how the gearbox works in most cars



4 STICK SHIFTING
The gear stick uses a spring-loaded ball joint to switch between each gear's dedicated selection rods.

3 SYNCHRONICITY
Gearboxes usually have a small clutch-style mechanism, called a synchromesh, that slows or increases each gear's speed so that the gear's teeth are engaged smoothly.

5 HOT RODS
These rods ensure that the correct gear is selected. Most have three of these forks, with each controlling two gears.

6 WHEEL POWER
The output shaft transfers the revised rotational power to the wheels at speeds they can handle.

7 COMPLEX COGS
Cogs of varying sizes represent the car's gears. Lower gears have larger cogs, while higher gears have smaller cogs.

8 COUNTERSHAFT
Beneath the gears you'll find the countershaft, which uses a larger gear to slow things down to more manageable speeds.

5 FACTS ABOUT GEARS

1 EARLY STAGES
A Canadian engineer called Alfred Horner invented the first automatic transmission in 1923, but he used compressed air rather than hydraulic fluid, so the system lacked power.

2 NATURAL SELECTION
Gears are also present in the natural world. A tiny bug called *Issus coleoptratus* has gear-like structures on its legs with interlocking teeth, used so it can jump in straight lines.

3 GEAR CHOICE
From 1930 to 1950, it was quite common to find cars with 'preselect' gearboxes. Drivers would have to choose their gear before pressing on the clutch pedal.

4 PADDLING
Formula 1 cars use semi-automatic sequential gearboxes with eight forward gears and one reverse gear inside their carbon-titanium gearboxes. Fully automatic systems have been illegal in F1 since 2004.

5 HEAVY MACHINERY
One of the world's biggest gearboxes can be found inside a wind turbine: it produces 10,000kNm of torque and weighs 86 tonnes.

© Alamy / Getty

HOW SAILS HARNESS THE WIND

Why some ships have different-shaped sails to others and how they're used

WORDS **AILSA HARVEY**

People have been sailing Earth's oceans for thousands of years, ever since the simple revelation that the surface of a cloth can catch the wind and propel an object floating on water. Today marine engines have become more economically viable, limiting traditional sailing to localised fishing industries and recreational activity. However, the evolution of ships' sails instigated human navigation across the oceans and resulted in global trade.

Many ancient cultures benefited from sailing, from Polynesian islanders who discovered untouched islands to the ancient Greeks' fishing boats. The earliest visual evidence of sailing boats dates back to 5500 BCE, found painted on a disc from ancient Mesopotamia.

As the advantages of sailing became better known over time, boat materials and technology were altered and experimented with to produce the most efficient sails. One of the greatest contributions to early sailing was the invention of the lateen. This is a triangular sail that runs from the front to the back of vessels. Sailors discovered that setting sails at a 45-degree angle allowed them to travel in the opposite direction of the wind in a zig-zag pattern. This technique is called tacking.

Ships' sails are drawn by pulling ropes attached to them

Did you know?

Some of the first sails were likely made of animal skin

FORE TOPGALLANT SAIL
Some ships have two topgallant sails per mast for easier handling.

EXTRA JIBS
Boats with multiple jib sails have increased stability.

FLYING JIB
This adds extra sail area to the front of the boat to bring the bow down and better balance the vessel.

FORESAIL
The lowest sail on the front mast is the principal sail used for steering a ship.

PRECISE PLACEMENT

The position of each sail plays an important role

DID YOU KNOW? The term ‘trade’ comes from the trade winds that allowed ships to sail across the Atlantic

FORE SKYSAIL
Skysails utilise the wind at higher altitudes.

FORE ROYAL
These sails sit just below the topsail. Only relatively large ships have these high royal sails.

MAIN SKYSAIL
This is usually the highest flying and centremost sail.

MAIN ROYAL
The royal sails are most beneficial in light winds.

MAIN ROYAL STAYSAIL
This sail harnesses crosswinds at the highest mast level.

MIZZEN SAILS
Ships with a mizzen mast can reduce the size of sails on other masts and increase a vessel’s balance.

DRIVER
This sail at the very back of the ship provides considerable stability and manoeuvrability.

MAIN TOPSAIL
On square-rigged ships, the topsail is the most commonly used sail.

FORE TOPSAIL
On the second-highest mast, above the foresail is the fore topsail.

TOPMAST STAYSAIL
Ships can have multiple small staysails in order to increase the number of sail combinations available.

MAIN TOPGALLANT SAIL
Generally, the main mast of a ship holds the largest sail.

MAINSAIL
Creating the lift that carries the ship forwards, the mainsail can be used alone to propel a ship.

RIG TYPES

The layout of a ship’s sails can differ significantly depending on where the ship was built, the size of the vessel and changes made to assist the boat’s specific use. Two main types of rig are the fore-and-aft rig and the square rig. The fore-and-aft sets the sails along the length of the ship, while a square rig crosses the width of the ship and lies perpendicular to it. Fore-and-aft ships were historically built for small crews and mainly served fishing communities and coastal trades. These rigs allow for quick changes in direction and are the best choice for navigating the fluctuating winds along coastlines. Meanwhile, square-rigged ships are designed for offshore sailing. These large sails were the most effective for utilising the prevailing winds that swept over the oceans when sailing traditional ships.

Fore-and-aft sails were invented around 1500 BCE

© Getty

Car headlights are vital bits of equipment, and they're surprisingly complex too

CAR HEADLIGHTS ILLUMINATED

Vehicle headlamps have been around for over a hundred years. How do they work, and what will they look like in the future?

WORDS **MIKE JENNINGS**

LOOKING AHEAD: LED VERSUS HID

LED headlights work when an electrical current passes through light-emitting diodes. There's no filament, thus no excess heat, and LED bulbs last longer than filament-based bulbs. LED bulbs shine brighter and further than traditional lights, and they also turn on instantly, but they can be expensive. High-intensity discharge (HID) headlights produce light using xenon gas, creating an arc of electricity between two electrodes. HID headlights are very bright, but HID bulbs can take several seconds to activate – and they're also quite pricey.

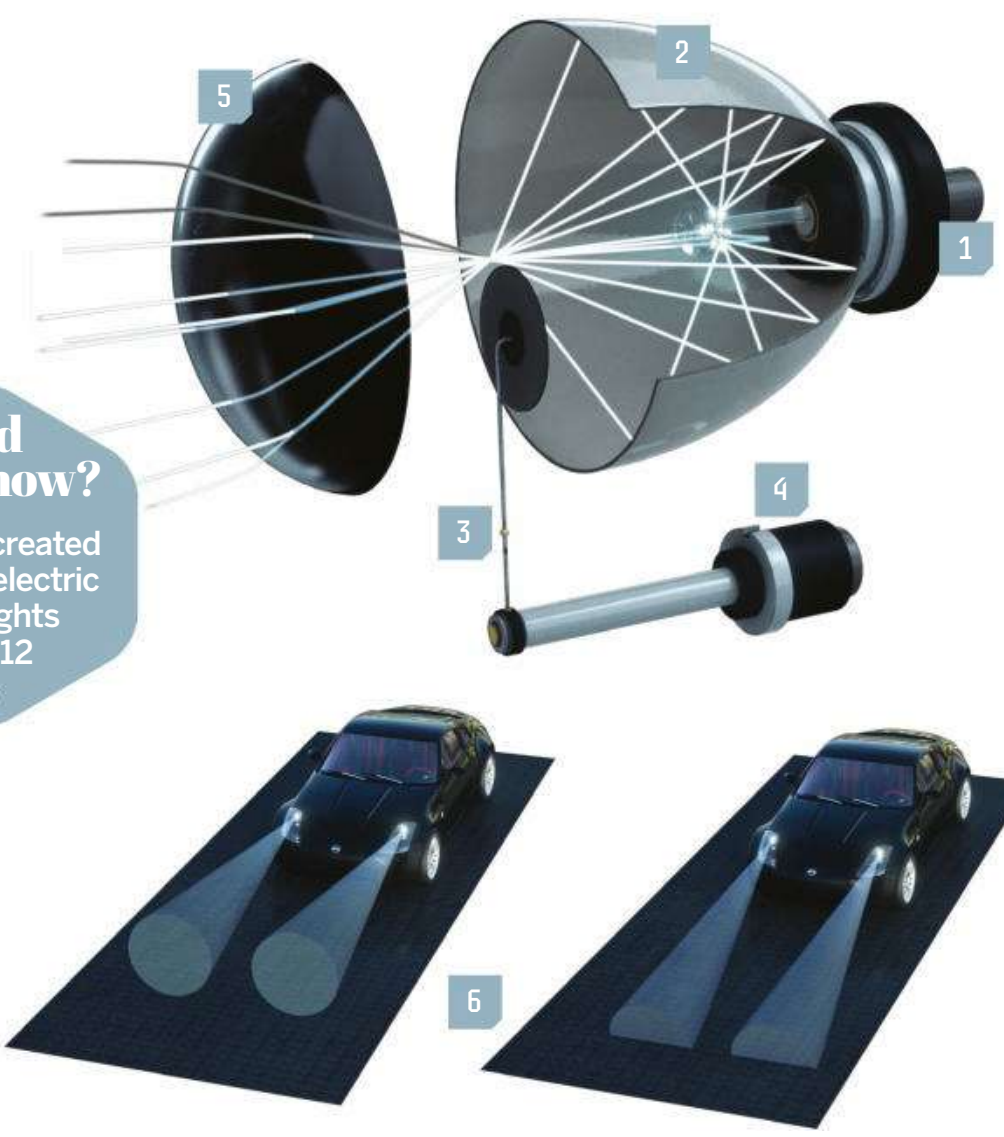
LED highlights are brighter and last longer than halogen bulbs

Headlights have come a long way since they were first introduced in the 1880s – back then they were literally gas flames. These days, most cars use halogen headlights that work in the same way as bulbs in your house. Inside the bulb is a combination of gases, including halogen, argon and nitrogen, surrounding a filament made of tungsten metal. When the lights are activated, an electrical current passes through the filament, heating it up, allowing the tungsten to interact with the gases to create light. The bulbs sit in a concave set of mirrors called reflectors, which strengthen the light and point it in the right direction. In older cars, this beam of light is what illuminates the road. Many newer cars go a step further, with projector systems that add a shield and a lens to create more focused illumination.

There are pros and cons to both designs. Reflector lights are cheaper, smaller and cover a larger area, while projector headlights are brighter, more consistent and have a more focused output. Whether they're basic reflectors or fancier projectors, there are several reasons why halogen bulbs are commonplace: they're cheap and they're easy to replace. Negatively, though, halogen bulbs aren't as efficient or as long-lasting as other types of headlight. It's those newer technologies that you'll probably see in more recent or expensive cars, as LED and high-intensity discharge (HID) headlights become more popular.

LIGHTING UP

Headlights are complex bits of kit. Let's take a look at how they work



Did you know?

Cadillac created the first electric headlights in 1912

1 FULLY CHARGED
The gas inside a halogen bulb interacts with an electrically charged filament to create light and heat.

2 FISHBOWL EFFECT
The bulbs sit inside a bowl of reflective mirrors that strengthens the light's unfocused output.

3 FOCUSING SHIELD
Projector lights have a shield that points the light towards the road so drivers get a stronger, more concentrated beam.

4 VARIED OPTIONS
Some projector lights have a solenoid that moves the shield, which means one bulb can create different types of beams.

5 CONVEX FLEX
Finally, a convex lens makes sure the beam points evenly in the right direction.

6 WHICH BEAM?
A dipped beam is ideal for bad weather, while the high beam is suitable for seeing for miles – though it distracts oncoming drivers.

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WHAT WAS THE V-2 ROCKET?

How this deadly weapon was repurposed as a vehicle for taking astronauts to space

WORDS **AILSA HARVEY**

A V-2 being transported

DID YOU KNOW? The V-2's first attack on London created a ten-metre-wide crater

The world's first large-scale liquid-propellent rocket was developed between 1936 and 1942 in Germany. It's regarded as a revolutionary breakthrough in rocket technology, with the use of liquid fuel increasing its thrust capabilities and making it the first artificial object to enter space. The V-2 was the most advanced rocket of its time when it was first launched in 1944. However, the purpose of its production was deadly. The 'V' in its name stood for 'Vergeltungswaffe', meaning 'vengeance weapon' in German. As the first long-range guided ballistic missile, the Nazis used the rocket to attack their enemies during World War II. During the war, these missiles killed around 9,000 people.

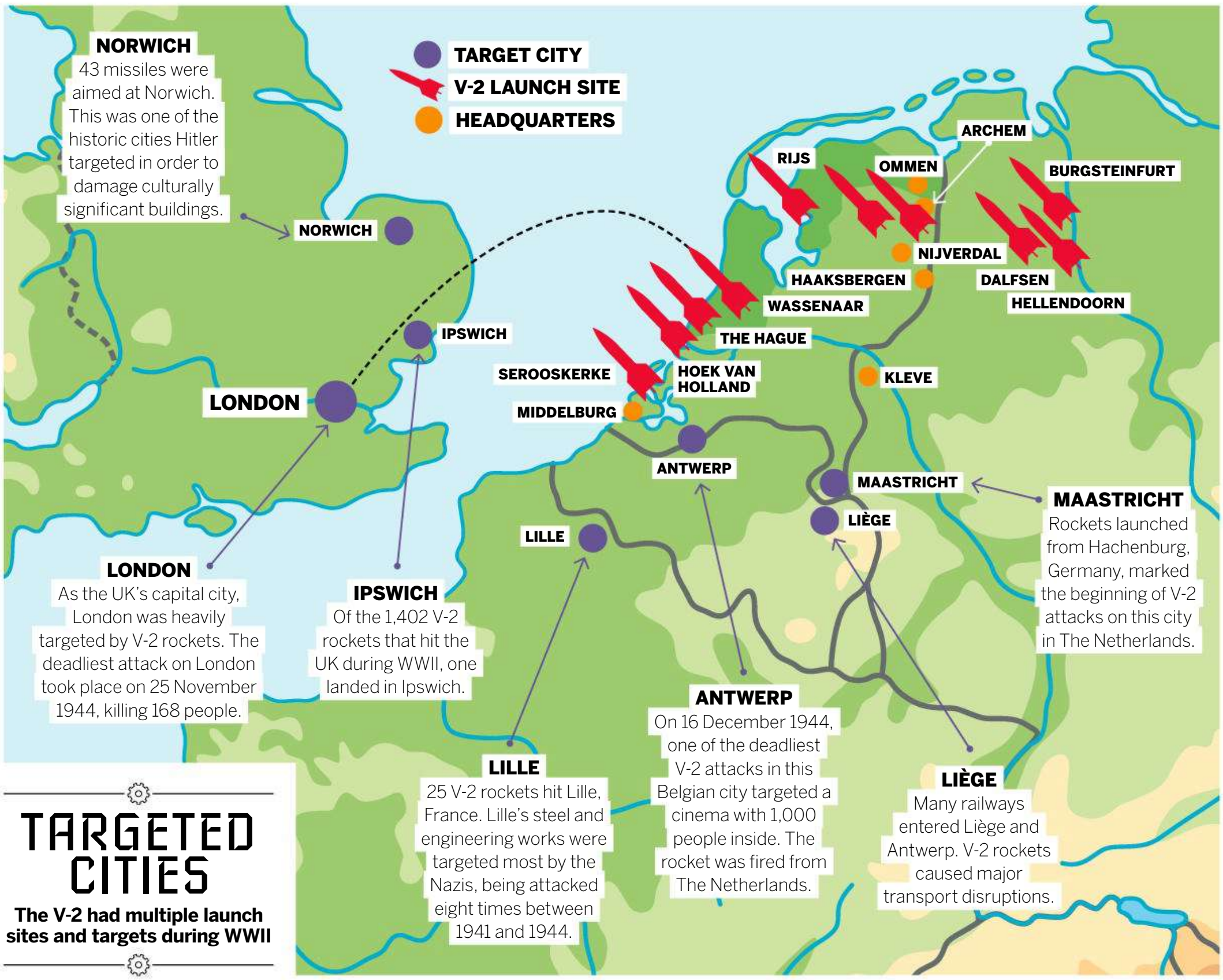
Each missile was 14 metres long, 1.6 metres wide and carried 900 kilograms of explosives. Along with the greater range that was achieved by the liquid propellant, the V-2 rocket was also equipped with a guidance system – something that provided it with much improved accuracy compared to its predecessors. Its automatic guidance system included an onboard computer which was programmed with the rocket's target destination. If the line of trajectory was altered, rudders in the rocket's fins could adjust to get it back on track.

Did you know?

American physicist Robert H. Goddard invented liquid-fuelled rockets

After the widespread use of the V-2 as a war weapon, the potential of the rocket's technology in future combat and space applications was realised. Soon after the war ended, the V-2, which was once responsible for taking so many lives, was the key to accelerating human exploration of space. Today liquid fuel is still the propellant of choice for space missions. The V-2 is remembered for its contribution to today's knowledge of distant worlds, but its origins and application in warfare aren't forgotten.

A crater left by a V-2 rocket near Palmers Green station, London, in November 1944


TARGET CITY
V-2 LAUNCH SITE
HEADQUARTERS
NORWICH
43 missiles were aimed at Norwich. This was one of the historic cities Hitler targeted in order to damage culturally significant buildings.
NORWICH
IPSWICH
LONDON
RIJS
OMMEN
ARCHEM
BURGSTEINFURT
NIJVERDAL
HAAKSBERGEN
DALFSEN
HELLENDOORN
WASSENAAR
THE HAGUE
SEROOSKERKE
HOEK VAN HOLLAND
MIDDELBURG
KLEVE
ANTWERP
MAASTRICHT
LIÈGE
LILLE
MAASTRICHT
Rockets launched from Hachenburg, Germany, marked the beginning of V-2 attacks on this city in The Netherlands.
LONDON
As the UK's capital city, London was heavily targeted by V-2 rockets. The deadliest attack on London took place on 25 November 1944, killing 168 people.
IPSWICH
Of the 1,402 V-2 rockets that hit the UK during WWII, one landed in Ipswich.
ANTWERP
On 16 December 1944, one of the deadliest V-2 attacks in this Belgian city targeted a cinema with 1,000 people inside. The rocket was fired from The Netherlands.
LILLE
25 V-2 rockets hit Lille, France. Lille's steel and engineering works were targeted most by the Nazis, being attacked eight times between 1941 and 1944.
LIÈGE
Many railways entered Liège and Antwerp. V-2 rockets caused major transport disruptions.

TARGETED CITIES

The V-2 had multiple launch sites and targets during WWII

© Getty / Alamy

AR ZONE

THE V-2 ARCHITECT

German engineer Wernher von Braun led the team who built the V-2 rocket. He was fascinated by rocketry from a young age and joined the Society for Space Travel at school, which set him on a path to becoming the technical chief of the rocket-development facility in Peenemünde, Germany. It was at this facility that he led the design and development of the missile. As a member of the Nazi party himself, von Braun was committed to producing a successful vengeance weapon.

After surrendering to the Americans during the war, von Braun shared his knowledge of the V-2 rocket with the US. Following WWII, he accepted the role of director at NASA's Marshall Space Flight Center. During his time there, he used his rocket-making skills for more beneficial purposes by helping design the rocket that took astronauts to the Moon.

Wernher von Braun holding a model of the V-2 rocket

Did you know?

Over 3,000 V-2 rockets were built during World War II

AR ZONE

SCAN HERE

ROCKET COMPONENTS

How this large liquid-propellant rocket was designed

1 ANTENNA
The antenna received and transmitted radio signals for missile tracking.

2 ENGINE
During combustion, this area reached temperatures between 2,500 and 2,700 degrees Celsius.

3 HYDROGEN PEROXIDE CONTAINER
Fuel and liquid oxygen pumps were powered by a steam turbine. Concentrated hydrogen peroxide produced this steam.

9 STABILISING FINS
The rocket's fins had a wingspan of 3.56 metres.

10 THRUST VANES
Small devices called vanes were placed in the rocket's exhaust to deflect thrust.

"The V-2 was the key to accelerating human exploration of space"

V-2 TIMELINE

2 Sep 1944
The V-2 rocket was declared to be operational.

7 Sep 1944
The first two V-2 rockets were fired, targeting Paris. But both crashed soon after launching.

8 Sep 1944
The first V-2 rocket to successfully hit its intended target was launched to Paris.

12 Oct 1944
Those in the German army who were responsible for launching V-2 rockets moved to The Hague in The Netherlands.

22 Oct 1944
V-2 rocket equipment was set up in The Hague, targeting London.

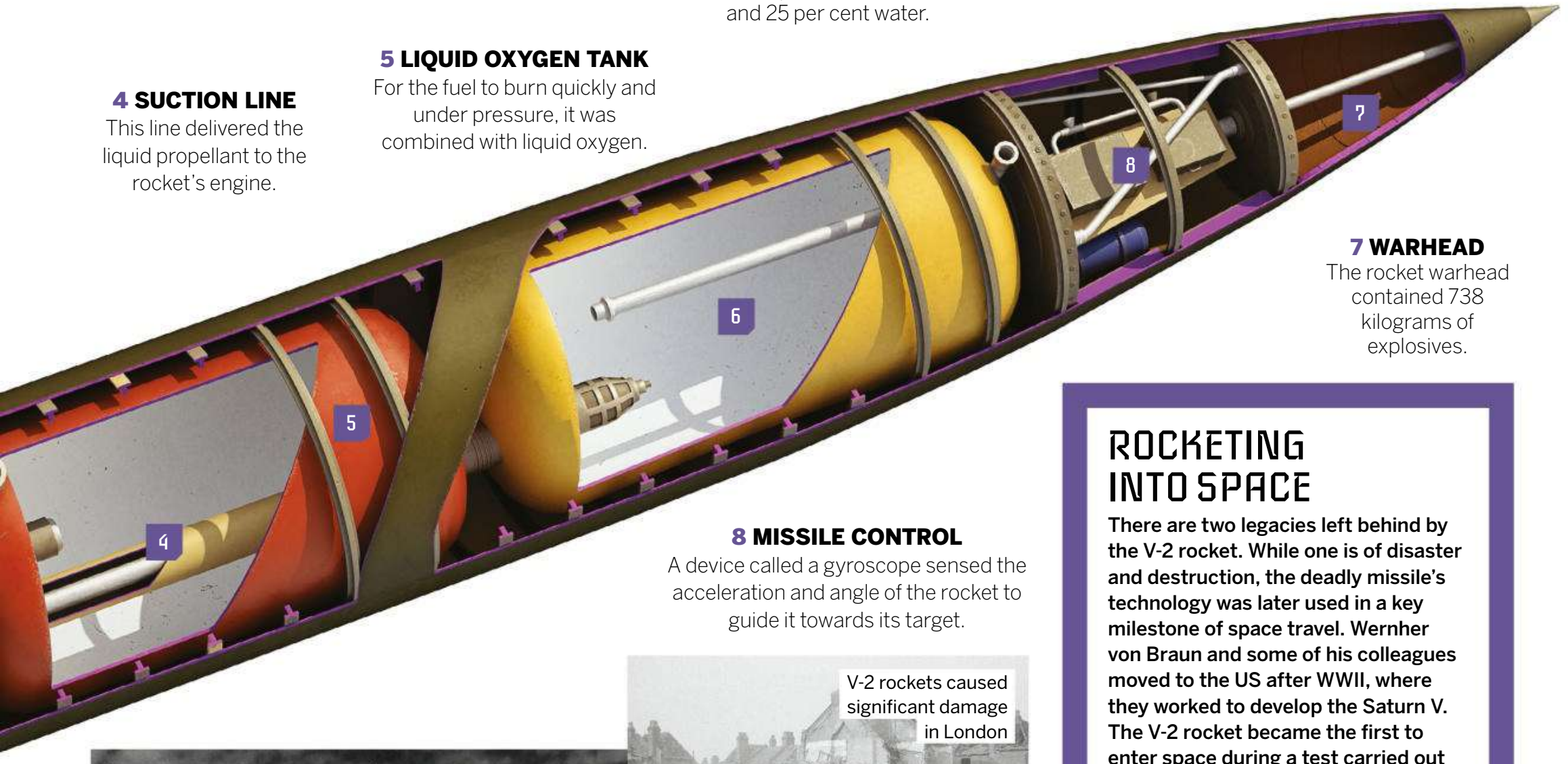
10 Nov 1944
UK prime minister Winston Churchill lifted a ban he had imposed on reporting rocket attacks to keep their accuracy secret.

DID YOU KNOW? At least 9,000 people died in V-2 attacks

6 FUEL TANK
This tank held a mixture of 75 per cent alcohol and 25 per cent water.

5 LIQUID OXYGEN TANK
For the fuel to burn quickly and under pressure, it was combined with liquid oxygen.

4 SUCTION LINE
This line delivered the liquid propellant to the rocket's engine.



7 WARHEAD
The rocket warhead contained 738 kilograms of explosives.

8 MISSILE CONTROL
A device called a gyroscope sensed the acceleration and angle of the rocket to guide it towards its target.

V-2 rockets caused significant damage in London

The first US test of a captured V-2 rocket in 1946

ROCKETING INTO SPACE

There are two legacies left behind by the V-2 rocket. While one is of disaster and destruction, the deadly missile's technology was later used in a key milestone of space travel. Wernher von Braun and some of his colleagues moved to the US after WWII, where they worked to develop the Saturn V. The V-2 rocket became the first to enter space during a test carried out by the Nazis in 1944. During this test, the rocket passed the boundary between Earth's atmosphere and outer space. After the war, US president Dwight D. Eisenhower moved the rocket development centre from the army to NASA to change the focus of von Braun's work. At NASA, the rocket scientist had to alter the advanced technology to produce a rocket that could stay in space rather than one designed to fall on cities. His team's experience in handling the large V-2 rocket assisted the US in the Space Race, with von Braun becoming the chief architect of the Saturn V launch vehicle. This vehicle successfully brought the first astronauts to the Moon in 1969.

The Saturn V rocket was the V-2's spacefaring successor

11 Mar 1945
The first unexploded V-2 rocket landed in the UK. It was studied on 7 April.

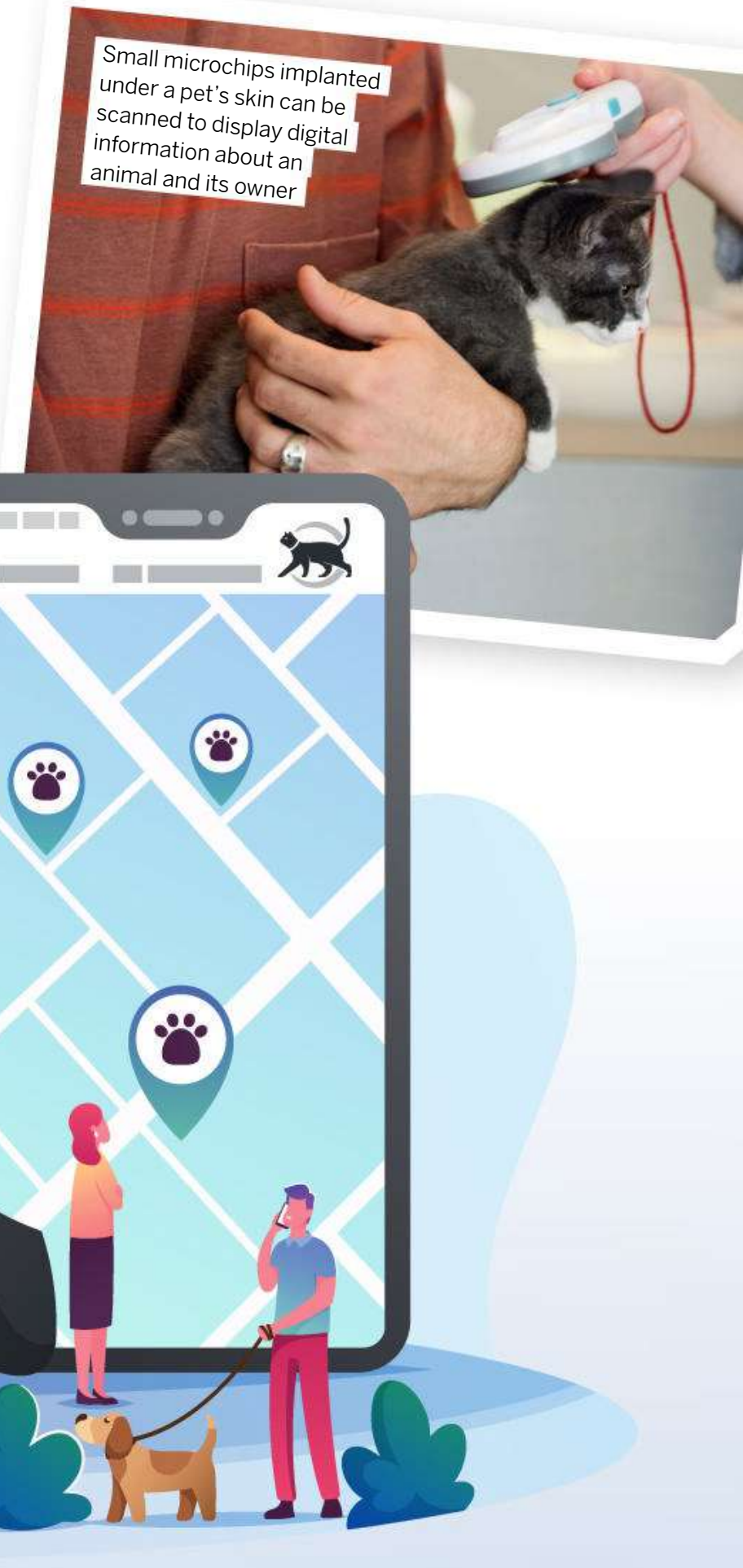
28 Mar 1945
The last rocket to be fired by the Nazis during the war targeted Antwerp, Belgium.

24 Oct 1946
A film camera attached to a V-2 rocket took the first photograph from space.

© Getty / Illustration by Nicholas Forder

HOW PET ID TAGS WORK

These smart devices reunite owners with their animal companions



Small microchips implanted under a pet's skin can be scanned to display digital information about an animal and its owner

WORDS **AILSA HARVEY**

No matter how much an owner adores their pet and takes precautions to keep them safe, it's still very common for animals to go missing. When this happens, it can be distressing for both pet and owner. Some of the main reasons for a pet getting lost include fear or anxiety, curiosity, hunting and mating instincts.

An owner only has to look away for a short time before completely losing track of their pet. Even if they spot them chasing something into the distance, dogs are often much faster than their owners, leaving them helpless. Meanwhile, cats, which don't require supervision and typically do their own thing, may leave an area they know well and struggle to return home.

Pet identification (ID) tags are worn by domestic animals to reunite lost pets with their owners. These tags display contact information and other important details about the animal. Without these, if a stranger finds a wandering animal, they have no way of knowing whether it's a loved and sought-after pet or a stray.

Keeping your pet's name and your contact information secured to your pet's collar enables others to inform you of your animal's whereabouts. But for those wanting to take a more active role in the search, tracking tags prevent owners from having to helplessly wait for news. These smart tags vary in range, but some can provide digital information about an animal's whereabouts and live tracking details as soon as a pet is lost.

This dog is wearing a GPS tracker around its neck

DID YOU KNOW? Some smart tags instantly alert animal shelters and rescue groups within a set radius of a pet's last known location

QR stands for 'quick response'

DIGITAL PROFILE

Some pet collars display a QR code instead of written information. These need to be scanned by a smartphone camera. Today many people carry their phones with them everywhere, so reporting sightings of animals that appear lost is quicker and easier than ever. Using QR codes means that more details about a pet – such as contact details, medical information and photographs – can be stored in a small space on the ID tag. As long as the person who finds the missing animal has a smartphone and access to the internet, when they scan the QR code, they will get instant access to this helpful information.

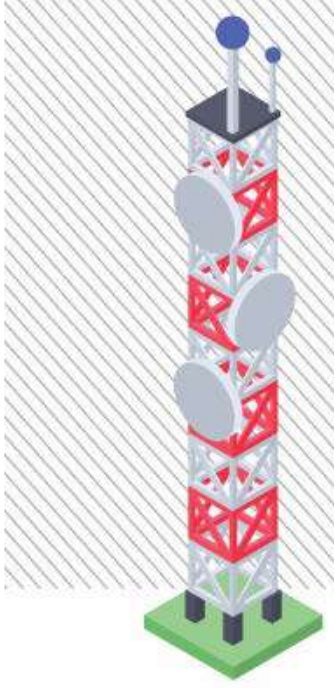
When the collar tag is scanned, the phone screen will display the animal's profile. This can store multiple emergency contact numbers in one place to ensure that the person who has found your pet will be able to get into contact with someone. Digital tags are also more flexible, as owners can change their details online. This feature means details can also be temporarily changed – to a pet sitter's, for example – when the owners are elsewhere. Without this flexibility, a lost or broken phone could reduce the chances of an owner seeing their pet again.

Did you know?

12 to 18 per cent of cats go missing at least once in a five-year period

TRACKER TYPES

There are three main systems that can be used to track down a lost pet

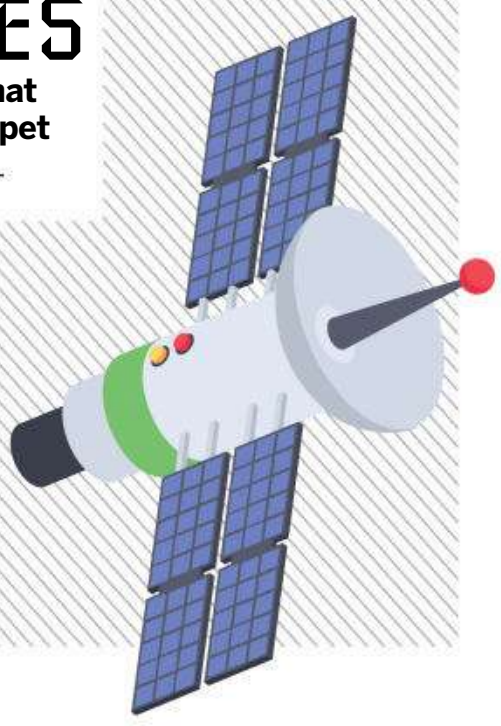


RADIO

Radio frequencies can be used to locate a missing pet. Signals are released from the animal's collar and picked up by the owner's transmitter. On the screen, the direction and distance are displayed. These trackers are relatively bulky, and so can't be used easily on small animals. They are used across short distances and require the owner to be able to travel to their pet.

CELLULAR

These use mobile phone masts to retrieve an animal's location. Cellular trackers are most beneficial in built-up areas with good mobile phone signals. They are accurate when a pet is lost within a few street blocks. As this uses mobile data, these trackers usually have an additional monthly cost.



GPS

Using satellites to locate an animal's whereabouts, GPS trackers can show owners live tracking data on a digital map. For as long as a pet is wearing a working tracker, owners can see the location of their pet on their phone screen, even from the other side of the world.

DO ALL DOGS NEED TAGS?

It's illegal in many countries, such as the UK, US, Canada and Australia, for dogs to be walked in public without an ID tag on their collar. In the UK these tags must include at least a name and address, otherwise dog owners can receive a fine of up to £5,000 ($6,550). There are some exceptions to this law. In UK legislation, this includes dogs used for sport, to control cattle and sheep, for emergency or rescue purposes and guide dogs. All dog owners should check the law in their local area, because these laws can vary by country or regions of the same country.

Guide dogs don't always require ID tags, but many owners choose to take this precaution

© Getty

INSIDE AN INFRARED CAMERA

These devices detect thermal energy and turn it into an image we can see

WORDS **SCOTT DUTFIELD**

Thermal-imaging cameras are unlike the camera found on your smartphone. A typical camera observes wavelengths of light in the visible spectrum that bounce off objects and hit receivers in the camera. The camera will then turn that light into an image. Thermal cameras, on the other hand, ignore visible light and seek out other wavelengths, called infrared. Infrared is a type of low-frequency electromagnetic radiation that's felt as heat. This is because infrared radiation excites molecules, causing them to move around and vibrate, which causes a temperature rise.

Every object in the known universe gives off some degree of infrared radiation, even if it's only a bit above the lowest theoretical temperature, absolute zero, equal to -273.15 degrees Celsius. The amount of infrared radiation given off correlates to the temperature of an object. The hotter an object gets, the more infrared it emits. Until an object is hot enough to emit a glow of visible light, such as molten metal, the only way to 'see' temperature is with a thermal camera.

Thermal-imaging cameras use a series of sensors and thermal detectors to estimate the level of infrared in front of them. The onboard sensors convert infrared signals into electrical currents. These currents are then translated into a colour-coded image to show fluctuations in temperature and infrared radiation.

The thermal camera displays a live infrared map that can instantly outline differing temperatures.

Did you know?

Around 50 per cent of the Sun's rays are infrared

"A series of sensors and thermal detectors estimate the level of infrared in front of them"

The concept of thermal imagery is not a recent one, dating back to 1929 when Hungarian physicist Kálmán Tihanyi created the first infrared-sensitive camera. Since then, the technology of thermal-imaging has evolved to become a useful tool in many different industries, including construction and engineering, security and medical diagnostics.

Thermal imaging can be used to monitor a person's body temperature

DID YOU KNOW? Infrared radiation can penetrate up to five millimetres into the skin

AR zone SCAN HERE

BEHIND THE LENS

How thermal cameras seek out heat

1 LENS
The lens of a thermal camera focuses incoming infrared radiation through a series of detectors.

2 DETECTORS
This focused infrared radiation hits tiny detectors set in a grid that correspond to the pixels in an image.

3 THERMOGRAPH
All the detectors create a pattern called a thermogram. The infrared radiation is converted by the thermograph into electrical impulses.

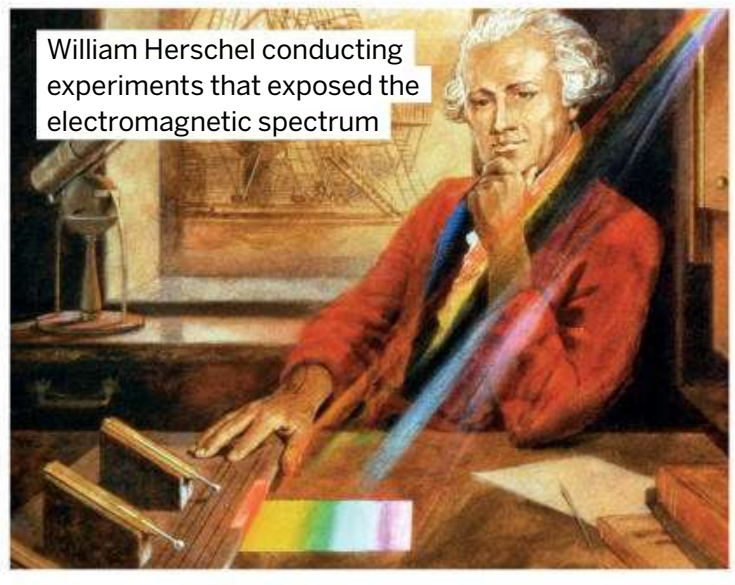
4 PROCESSOR
Electrical impulses are translated into data that corresponds to the pixels of an image.

5 COLOURED IMAGE
Data from the processor dictates the colour of each pixel on the display depending on its correlating temperature.

6 COLOUR CODING
The hottest temperatures are displayed in bright white, red and orange. Purple, blue and black represent cold.

FINDING INFRARED

British astronomer Sir William Herschel is responsible for the discovery of infrared radiation in 1800. Through a series of experiments, Herschel set a prism at a south-facing window in direct sunlight to direct and separate light into the different wavelengths, and subsequently different colours, that make up visible light. He then exposed a thermometer to each of the different colours to see how they might change the temperature displayed. However, he found that when the thermometer was placed outside the visible light past the red end of the light spectrum, the temperatures continued to increase. What he had discovered was infrared radiation.


William Herschel conducting experiments that exposed the electromagnetic spectrum

5 USES FOR INFRARED CAMERAS

1 FINDING WIRES
Thermal imaging can be used to evaluate different cables and connections that are hidden behind walls. In spotting active wires, engineers can conduct maintenance and detect faults.

2 SECURITY
Police officers and law enforcement can use thermal imaging to locate criminals in adverse weather, darkness or in obscured environments such as woodland.

3 HEALTH CHECK
Veterinarians use thermal imaging on the joints of animals to detect hotspots that may be caused by autoimmune conditions, such as arthritis, without the need for surgery.

4 HEAT LOSS
Thermal imaging can be a handy tool for locating cold spots and moisture during building surveys. This can also be used to evaluate the overall integrity of the building's structure.

5 FIREFIGHTING
Firefighters can use thermal imaging to detect hotspots in a burning building and make decisions on the best course of action. It's also a useful tool to locate people trapped by smoke.

© Getty / Illustration by Adrian Mann

GAMING PC TEARDOWN

A closer look at what makes the most powerful gaming computers tick

WORDS **MARK SMITH**

There are over 3 billion gamers – 40 per cent of the world's population. Of those, 1.5 billion are dedicated PC gamers

The games industry is now bigger than Hollywood and the sports industry combined, and there are more than 3 billion gamers on Earth. With developers competing for all those customers, it's no surprise that games are getting bigger, better and slicker all the time. But in order to make them look, sound and play as good as they possibly can, the machines that bring everything to life have to be packed with top tech.

Gaming PCs feature ultra-powerful processors and tons of memory to allow the computer to process lots of information. They also have top-of-the-line graphics and sound cards to process data, making them look and sound much better than a regular office PC. But to keep all that technology running smoothly these things need lots of power, and that power generates heat. Powerful gaming PCs often have an array of fans to protect their components from overheating and breaking down.

Did you know?

Surgeons who play games make 37 per cent fewer mistakes

Another way to make gaming PCs stand out from the regular computers we use for everyday tasks is to make them look awesome. From speakers that light up and transparent tower cases to ergonomically designed keyboards, gaming PCs can really look out of this world, and can be fully customised. One reason gaming PCs are popular is that they have a huge catalogue of games – much bigger than the latest consoles. While the latest consoles often only have limited backwards compatibility – meaning they can't play some older games from previous eras – PCs have no such problems. If you want to take a break from the latest releases, you can boot up a classic from 15, 20 or even 30 years ago.

Gaming PCs are also regular computers too, so when they're not being used for video gaming, all that top hardware makes them run smoothly when it comes to the more conventional stuff like surfing the web, doing homework or running a home office.

Russell's *Spacewar!* is considered the first video game

A PROUD TRADITION

PC gaming is a very particular and proud niche that can trace its roots all the way back to 1962. It began when Stephen Russell led a team of programmers at the Massachusetts Institute of Technology (MIT) to develop a game called *Spacewar!*. The young computer programmer and his fellows designed the game for a PDP-1, a computer the size of a car. And while the graphics were pretty basic, they held up quite well compared to some of the games available even as late as the 1980s. Today PC gaming inspires an avid following, and many players take the actual performance and look of their computers almost as seriously as their gaming, 'overclocking' the components to many times their rated speeds and installing RGB lighting into bespoke PC cases.

DID YOU KNOW? The average age of a gamer is 34 – many grew up playing games

THE BEAST UNDER THE BONNET

Gaming desktops are packed with some of the very best computer components

1 CPU

The brains of the PC. The faster the clock rate, the more up-to-date games the system will be able to handle without slowing down.

2 FANS

Fans are often industrial quality to stop the components from overheating, which can cause the computer to crash.

3 GRAPHICS CARD

A graphics processing unit (GPU) is like a second brain. While the CPU runs the rest of the system, the GPU just takes care of the graphics.

4 MOTHERBOARD

This is where the components sit together, including the CPU and memory. Gaming PCs can be upgraded with extra memory and more powerful processors so they can take on more complex tasks.

5 POWER SUPPLY

This converts the alternating high-voltage current (AC) from your house into direct current (DC) that the computer needs to run. This has got a fan too.

6 RAM

Random Access Memory is the computer's short-term memory, used to load and run games and applications.

7 DRIVES

A solid-state drive (SSD) is where everything – including games – is stored on the computer; they're gradually replacing the noisy and heavy mechanical hard disk drives of old.

8 TOWER CASE

Gaming cases are designed to have lots of room because the components are modular, meaning you can add and replace things to upgrade performance.

9 NVME DRIVE

The latest in storage technology – even faster and smaller than modern SSDs. They're installed directly into the motherboard like a stick of RAM.

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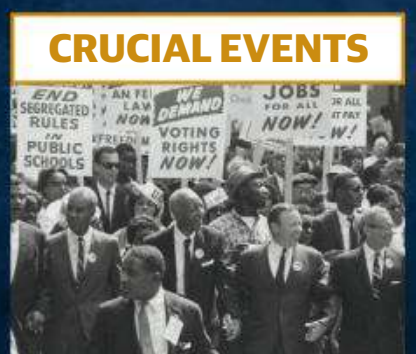

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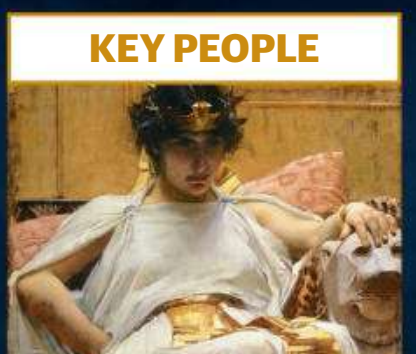
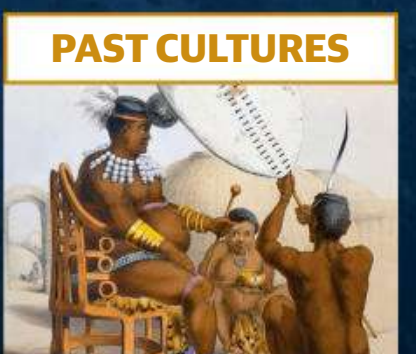


KEY PEOPLE

GREATEST BATTLES



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WHAT CAUSES WIND?

How the uneven heating of our planet produces everything from a light breeze to a full-force gale

WORDS **AILSA HARVEY**

Earth's atmosphere is structured into five main layers. From the closest to farthest from Earth's surface, these are the troposphere, stratosphere, mesosphere, thermosphere and exosphere. The air gets thinner as the distance from the planet's surface increases, but each of these atmospheric layers displays turbulence. Air particles are constantly churned both vertically and horizontally; this turbulence is also known as wind. The wind we experience when we venture outside is in the troposphere, and it can vary extremely in temperature and strength. But what causes these tiny particles to move so ferociously, and in unison, that the feeling of wind hitting the skin can be as strong as a slap in the face?

Air changes position in the atmosphere as its pressure alters. When its particles gain heat – and energy – they move more, creating larger gaps between particles and reducing density. This causes the warmer air to rise above denser particles and creates flows of air.

Earth's atmospheric pressure isn't uniform, so the atmosphere is never going to be still. The further from the equator you are, the lower the air pressure will become at the same altitude. Winds that blow due to these differences are called planetary or prevailing winds. Other winds, which aren't permanent, are those created by changes in seasons, called periodic winds, and winds created by local weather and terrain.

Strong winds can be life-threatening and damaging to trees and buildings, but the presence of wind also benefits the planet. In different layers of the atmosphere, water vapour, energy and other substances are distributed by the moving air. At ground level, this movement keeps people and animals cool, distributes the seeds of plants and generates renewable electrical energy.

DID YOU KNOW? The term ‘katabatic winds’ comes from the Greek word katabasis, meaning ‘going down’

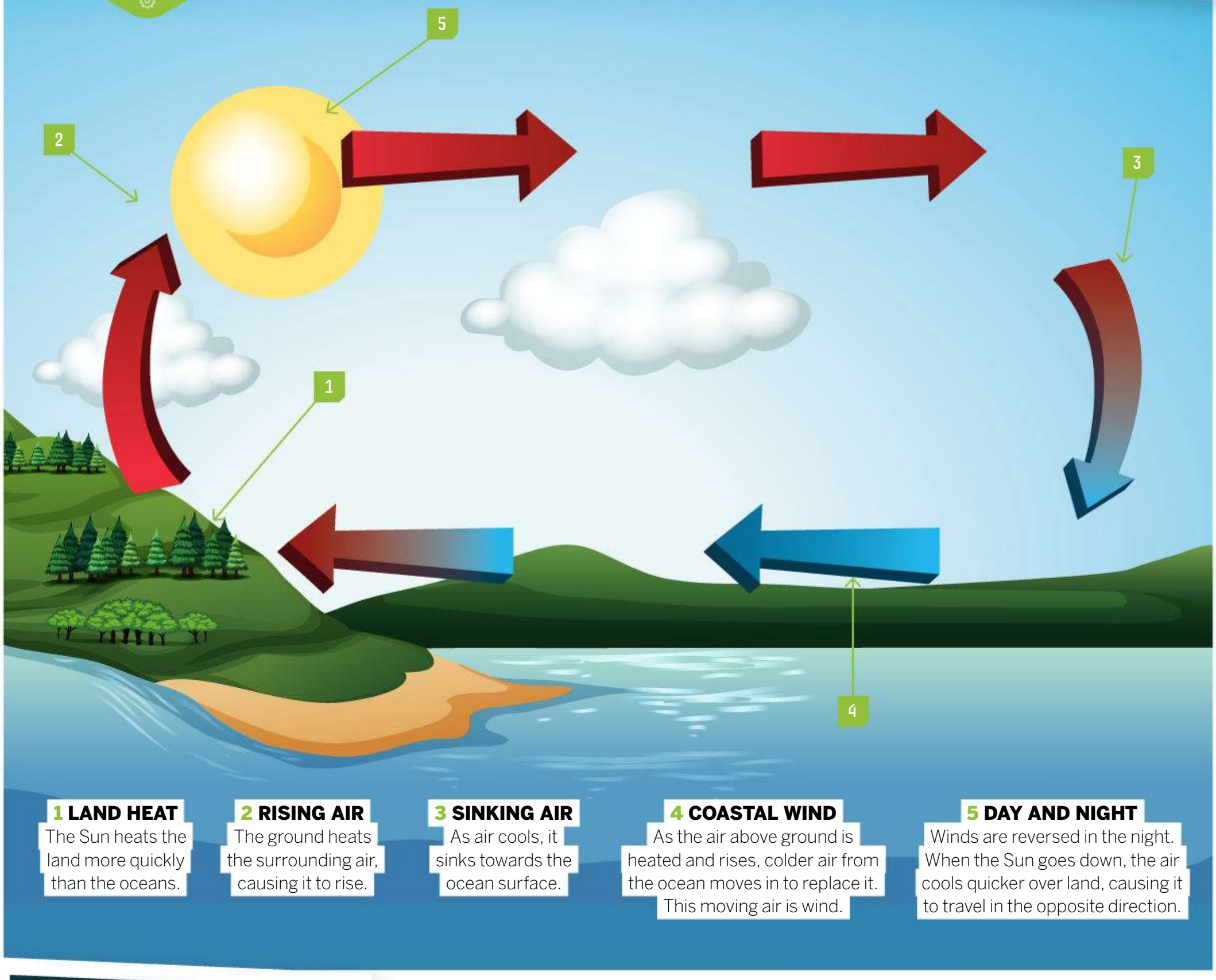
Tornadoes form when warm, humid air collides with cold, dry air

Did you know?

The Beaufort wind force scale was invented in 1805

THE WIND CYCLE

A rush of air is generated by the planet’s varied surfaces



1 LAND HEAT
The Sun heats the land more quickly than the oceans.

2 RISING AIR
The ground heats the surrounding air, causing it to rise.

3 SINKING AIR
As air cools, it sinks towards the ocean surface.

4 COASTAL WIND
As the air above ground is heated and rises, colder air from the ocean moves in to replace it. This moving air is wind.

5 DAY AND NIGHT
Winds are reversed in the night. When the Sun goes down, the air cools quicker over land, causing it to travel in the opposite direction.

An anemometer usually has three or four cups

HOW METEOROLOGISTS PREDICT AND MEASURE WIND

When predicting future weather, meteorologists rely on a variety of tools to collect extensive data about the atmosphere. Satellites can track the motion of clouds by producing a series of images. From this information, forecasters can predict where the winds will travel next. Many instruments can be used to collect data about wind. Cup anemometers are tools that rotate at rates proportional to the speed of wind. To achieve this, specially designed conical cups are attached to the instrument’s axle for the wind to blow into. As this happens, the cups rotate. Because wind intensity can change quickly in short periods of time, it’s measured as the average speed and direction of wind over a ten-minute period. Wind is defined as a gale when an average speed of 39 miles per hour is achieved in this period.

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THE WINDIEST PLACE ON EARTH

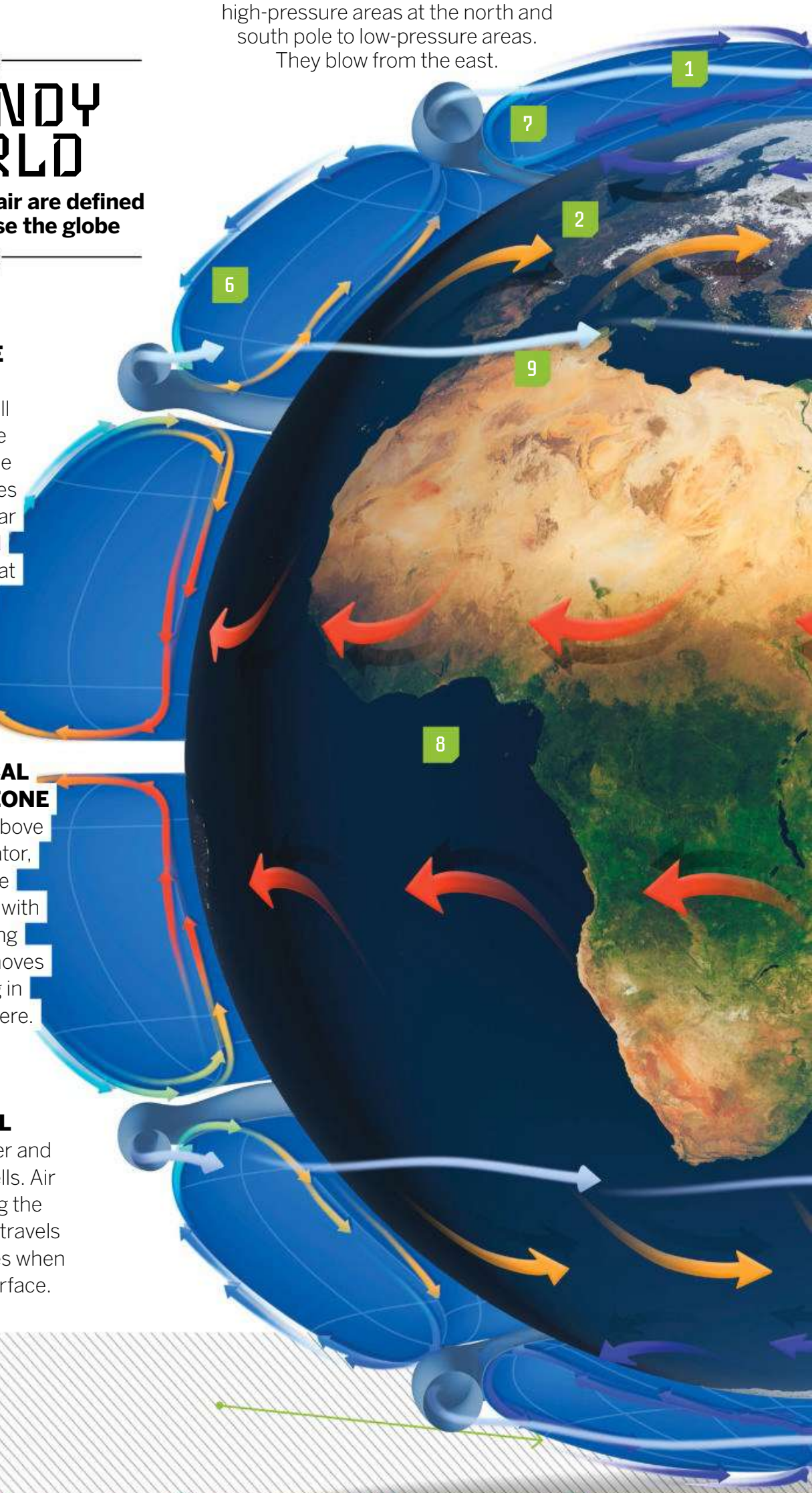
Every winter, winds in Antarctica reach speeds of over 100 miles per hour. The continent experiences such strong gusts as a result of katabatic winds. Katabatic winds are created by the extremely cold temperatures of Antarctica. The cold, dense air lying above the icy surface travels downwards towards the coast due to gravity and pressure differences between dense and thinner air.

A coastal area of Antarctica called Commonwealth Bay is regarded as the windiest place on the planet. In this 37-mile-wide region, winds regularly travel at more than 150 miles per hour. Due to the crescent shape of the bay, katabatic winds travelling into Commonwealth Bay are forced into its narrow space. This increases wind speed as air passes through, contributing to the bay's average annual wind speed of 50 miles per hour.

Adélie penguins use Commonwealth Bay as a breeding ground despite the extreme winds

A WINDY WORLD

How streams of air are defined as they traverse the globe



1 POLAR EASTERLIES
These dry winds move from cold, high-pressure areas at the north and south pole to low-pressure areas. They blow from the east.

6 MID-LATITUDE CELL
The airflow in this cell moves in the reverse direction to that in the Hadley cells. Air moves towards the poles near Earth's surface and towards the equator at higher altitudes.

8 INTERTROPICAL CONVERGENCE ZONE
About five degrees above and below the equator, trade winds move southwest, colliding with trade winds moving northwest. The air moves upwards, resulting in little surface wind here.

7 POLAR CELL
Polar cells are smaller and weaker than other cells. Air sinks when reaching the highest latitudes and travels towards lower latitudes when it reaches Earth's surface.

THE BEAUFORT SCALE

The numbers of this scale correlate to the force of wind

0: CALM AND STILL
<1 MILES PER HOUR
Smoke rises vertically.

1: LIGHT AIR
1 TO 3 MILES PER HOUR
Wind direction can be shown by smoke drift. The sea is rippled.

2: LIGHT BREEZE
4 TO 7 MILES PER HOUR
Leaves rustle on trees and wind is strong enough to move wind vanes.

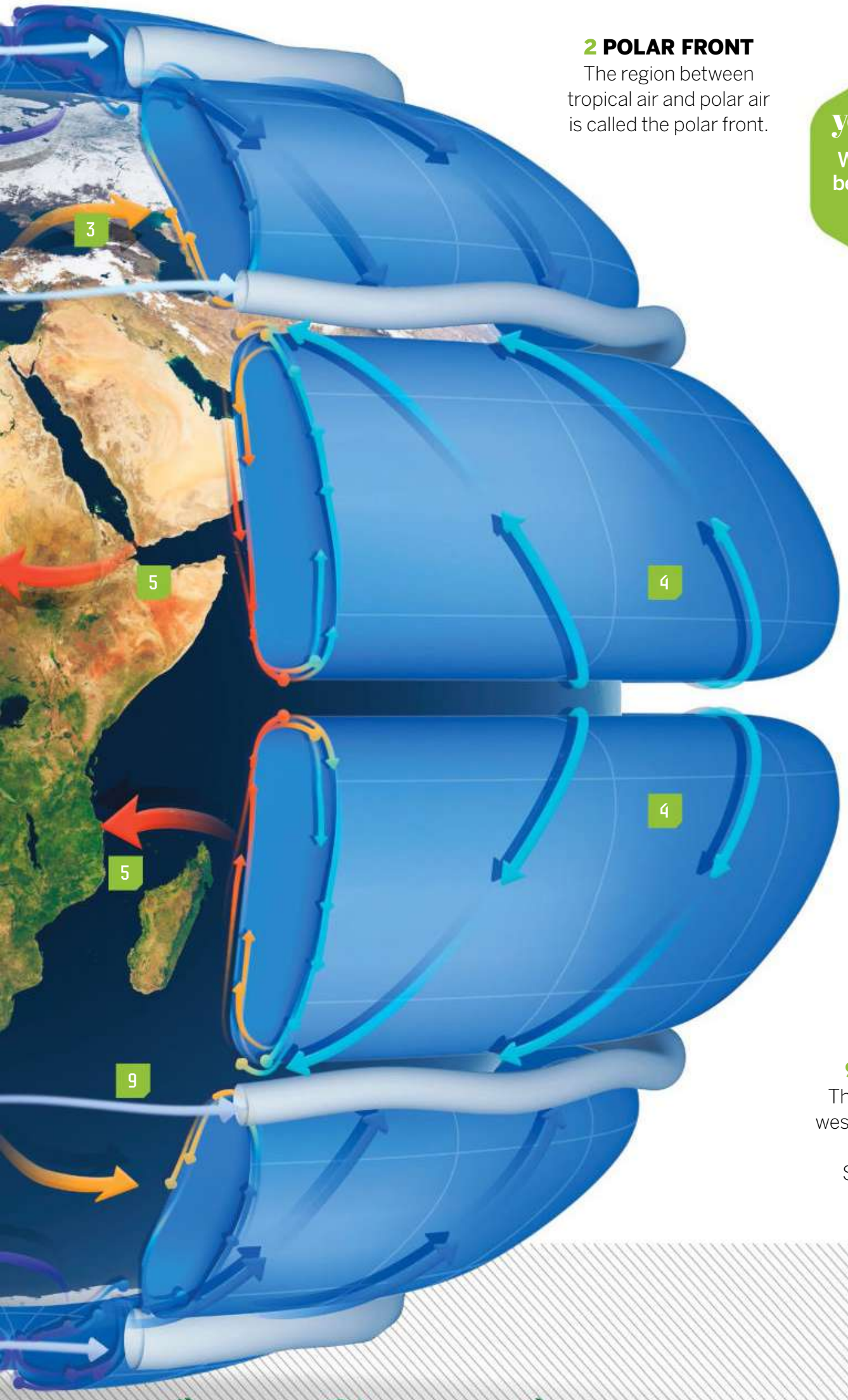
3: GENTLE BREEZE
8 TO 12 MILES PER HOUR
Trees' twigs constantly move. Small flags fly in the wind.

4: MODERATE BREEZE
13 TO 18 MILES PER HOUR
Dust and small branches can be lifted. Small waves form in the sea.

5: FRESH BREEZE
19 TO 24 MILES PER HOUR
Moderate-sized waves form. Small trees sway.

6: STRONG BREEZE
25 TO 31 MILES PER HOUR
Large branches move and large waves form.

DID YOU KNOW? The largest hurricane on record had a diameter of around 1,380 miles



2 POLAR FRONT
The region between tropical air and polar air is called the polar front.

3 WESTERLIES
In the middle latitudes – between 30 and 60 degrees – westerlies are the prevailing winds from the west. They often produce anticyclones.

4 HADLEY CELLS
These cells make up the global tropical atmospheric circulation. Air rises near the equator and moves towards the poles.

5 TRADE WINDS
These easterly winds blow around Earth near the equator. Trade winds produce ocean currents, used by early sailing ships and modern commercial ships for quicker journeys.

9 HORSE LATITUDES
The regions of calm air where westerlies and trade winds meet in both the Northern and Southern Hemisphere are called horse latitudes.

Hurricanes rotate clockwise in the Southern Hemisphere and anticlockwise in the Northern Hemisphere due to the rotation of Earth

Did you know?

Windmills have been used since 2000 BCE

5 FACTS ABOUT WIND PATTERNS

1 JET STREAMS
Earth has four main jet streams. These strong and narrow bands of wind blow from west to east across the globe.

2 HURRICANES AND CYCLONES
These large, spiralling storms produce winds of at least 74 miles per hour. These systems form above warm water and can move over land to cause devastation.

3 TORNADOES
These narrow columns of air rotate violently. Tornado winds can travel at 200 miles per hour and connect thunderstorms to the ground.

4 BLIZZARDS
When storms carry and release considerable volumes of snow, they are known as blizzards. They greatly reduce visibility and have winds exceeding 35 miles per hour.

5 TYPHOONS
This wind pattern is similar to a hurricane, but forms in the northwest Pacific Ocean. Japan, the Philippines and China are the largest countries affected by typhoons.

7: NEAR GALE
32 TO 38 MILES PER HOUR
It becomes difficult to walk against the wind. Foam is blown across the sea.

8: GALE
39 TO 46 MILES PER HOUR
Twigs break from trees.

9: STRONG GALE
47 TO 54 MILES PER HOUR
Buildings can be damaged, such as roof slates being blown off.

10: STORM
55 TO 63 MILES PER HOUR
Trees are uprooted. Damage is caused to buildings and other structures.

11: VIOLENT STORM
64 TO 72 MILES PER HOUR
Widespread structural damage. The sea is covered in white foam and large waves.

12: HURRICANE
73+ MILES PER HOUR
Ocean foam and spray fills the air. There is significant structural damage.

© Getty / Science Photo Library

HOW SMART IS A DOLPHIN?

These marine mammals are some of the cleverest creatures in the ocean

WORDS **SCOTT DUTFIELD**

Did you know?

Dolphins can recognise themselves in a mirror

Dolphins are commonly credited as being one of nature's smartest animals, often being compared to the heightened intellect of great apes or humans. Intelligence in the animal kingdom isn't measured solely on the size of the brain, but by how it compares to the overall mass of the animal. Neuroscientist Harry J. Jerison proposed in a 1973 paper that the ratio of body mass, actual brain size and expected brain size are related to an animal's cognitive ability. He invented a way to accurately represent the ratio between an animal's brain and body through a series of calculations.

These calculations are now called the encephalisation quotient (EQ), taking the volume of the brain to the volume of its expected body size into account. An EQ score compares one species' ratio to other similarly sized animals. For example, humans have the highest EQ of any primate, scoring between 7.4 and 7.8. This means that a human brain is seven to eight times bigger than an average mammal of comparable size. The EQ score of a bottlenose dolphin is around 5.2.

Other than the mass of a dolphin's brain, their cellular makeup also gives them an intellectual leg up on other animals. Von Economo neurons (VEN), also known as spindle neurons, are complex cells deep within the brain and have been associated with assisting in social awareness and interoception – the sense of what's going on inside your body. Some scientists have speculated that the presence of these types of neurons is related to individual differences in general intelligence.

Previously it was thought that great apes and humans were the only species to have these smart cells. However, some marine mammals, including some species of dolphins, also possess spindle neurons.

Along with their big brains, dolphins are also capable of complex social interactions and are known to create tight-knit communities which help one another survive. A group of dolphins, known as a pod, works together while hunting fish. In a coordinated assault, dolphins encircle a school of fish with ever-decreasing circles of bubbles, compacting and trapping the school and making individual fish much easier for the dolphins to pick off. Dolphins have also been known to collect heavy, fish-bearing conch shells, taking them to the surface and shaking the fish out for a quick bite.

A pod of long-beaked common dolphins hunting a school of fish

HALF ASLEEP

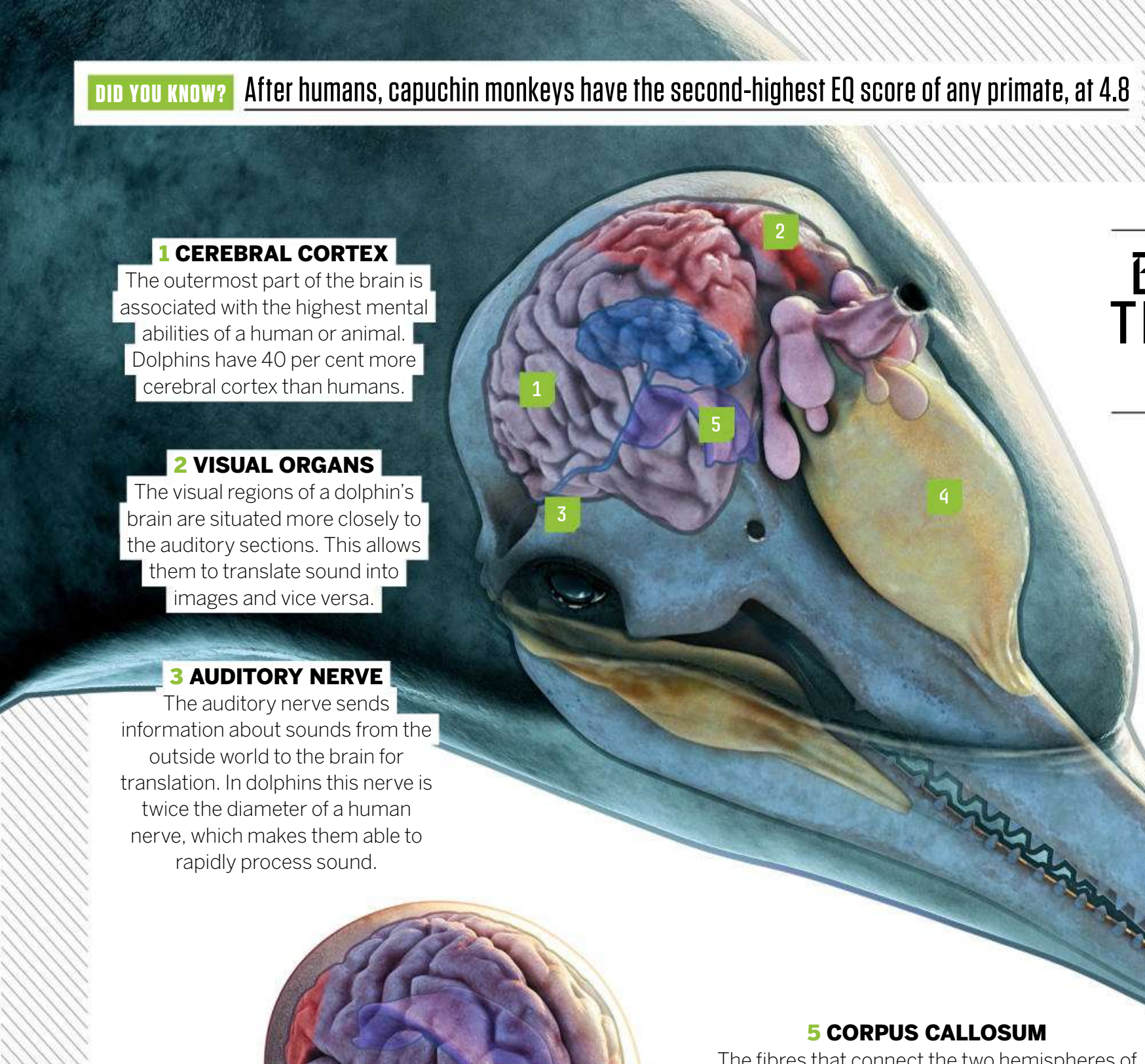
Spending your entire life living in water as a mammal makes sleeping without drowning a difficult feat. But dolphins have evolved an ingenious way to remain fully rested without filling their lungs with water. Rather than slipping into unconsciousness, dolphins can temporarily 'turn off' one side of their brain to rest, closing the opposite eye. The active hemisphere of the brain will remain conscious to ensure the dolphin rises to the surface to take a breath. Like humans, dolphins sleep at night, but only allocate around two hours of their time resting each hemisphere.

A dolphin resting on the surface of the water in Australia

DID YOU KNOW? After humans, capuchin monkeys have the second-highest EQ score of any primate, at 4.8

BATTLE OF THE BRAINS

Are dolphins' brains better than ours?



1 CEREBRAL CORTEX

The outermost part of the brain is associated with the highest mental abilities of a human or animal. Dolphins have 40 per cent more cerebral cortex than humans.

2 VISUAL ORGANS

The visual regions of a dolphin's brain are situated more closely to the auditory sections. This allows them to translate sound into images and vice versa.

3 AUDITORY NERVE

The auditory nerve sends information about sounds from the outside world to the brain for translation. In dolphins this nerve is twice the diameter of a human nerve, which makes them able to rapidly process sound.

4 MELON

One tool dolphins have that humans lack is their use of echolocation. A sensory organ in the front of their brain, called the melon, is a dolphin's acoustic lens for sound recognition.

5 CORPUS CALLOSUM

The fibres that connect the two hemispheres of the brain are collectively called the corpus callosum. This bridge of fibres is four times bigger in humans than dolphins due to dolphins' alternating brain activity while sleeping.

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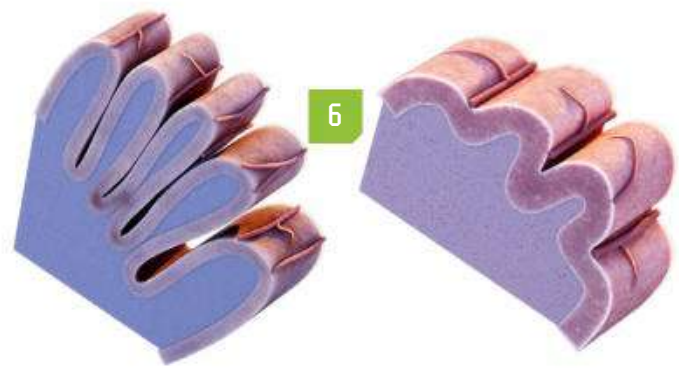


6 BRAIN FOLDS

Generally, a larger number of folds in a brain indicates higher intelligence. This is because the surface area of the brain is higher. An unfolded dolphin brain is around the size of six magazine pages; a human brain is only around four pages.

DOLPHIN SUPERSTARS

The largest bottlenose dolphins in the world live in the Moray Firth inlet in Scotland. They adapted to survive the cold, treacherous waters of the North Sea in many ways, from packing on insulating layers of blubber to understanding tidal fluctuations to find food. These amazing dolphins are also experts in saving energy and have taught themselves a neat trick: using just their tails to keep them in position, they swim against the current waiting for salmon on the incoming tide and gulp this tasty meal down headfirst. Just like us, these bottlenose dolphins – and some whale species – have special cells in their brains called spindle neurons, associated with advanced abilities like remembering, communicating, tool use and problem-solving. For more amazing dolphin facts, visit whales.org to find out how to help protect them. You can even adopt a Moray Firth dolphin and learn more about their fascinating lives.

Adopt a dolphin today with WDC and help protect Scotland's Moray Firth dolphins

© Getty / Charlie Phillips / Illustration by Nicholas Forder

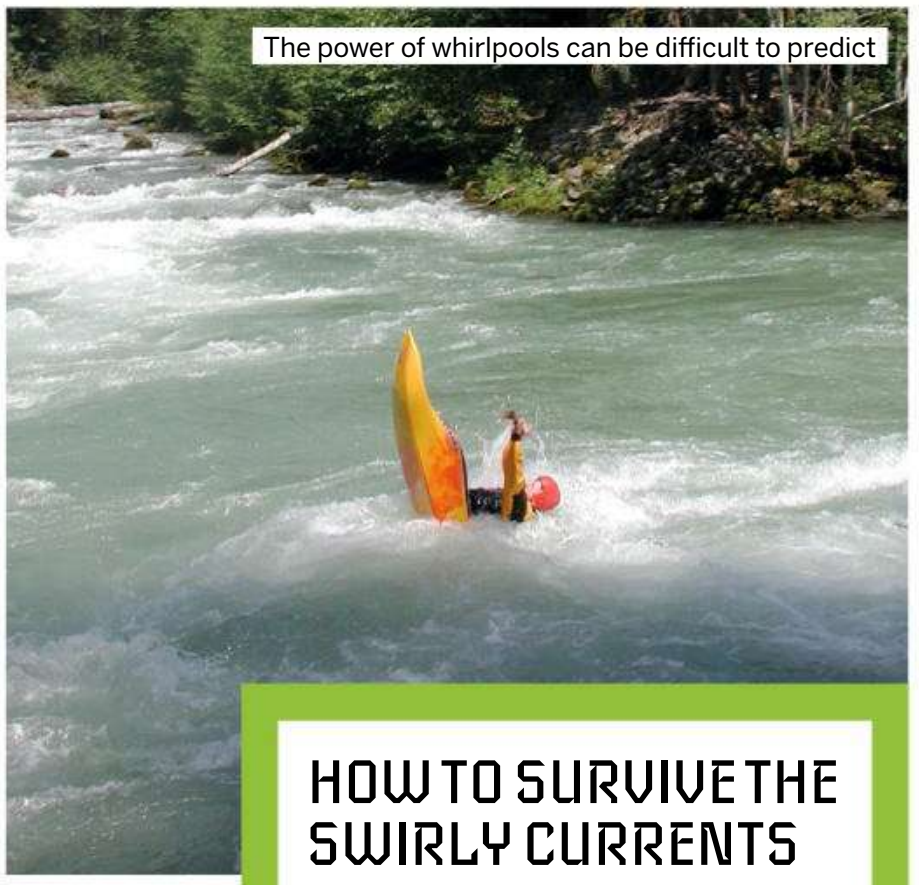
The Naruto whirlpools are produced by harsh tidal currents

HOW WHIRLPOOLS FORM

These ominous vortices have the power to suck nearby objects into a watery spiral

WORDS **AILSA HARVEY**

When you pull the plug out of a sink full of water, the water starts to move in a circular motion towards the drain. As it gets closer to the drain, this movement accelerates, and a column of swirling air can appear above it. This display is similar to a phenomenon that appears in nature, called whirlpools. Fast-flowing currents in oceans and rivers constantly change direction. When water moving in two different directions comes into contact, the two streams interact in an unusual way. They can't continue to travel at the same speed and direction through one another, so they are forced to turn and swirl around each other. Depending on the volume of water and the force of colliding waters, whirlpools can appear in different sizes. Some whirlpools form and disappear over a short period of time, while others have existed for centuries. Larger and more dangerous whirlpools are called maelstroms. These hold the power to fatally engulf anyone who comes too close.



The power of whirlpools can be difficult to predict

HOW TO SURVIVE THE SWIRLY CURRENTS

Whirlpools aren't as destructive as they are portrayed in fiction, such as the whirlpool battle in *Pirates of the Caribbean*, but they do pose danger to people and small boats. Most people won't experience the entrapment of a whirlpool's force, but for many, such as avid kayakers, it's useful to know how to survive one. Make sure to wear protective gear when entering the water, such as a life vest and helmet. These can protect you from the harsh currents surrounding whirlpools. If you see any signs of whirlpools, it's best not to enter the water at all. If you end up entering one, don't move in the same direction as the water flow, and aim for the outer edge rather than the centre. When in a boat or kayak, try to prevent the boat from filling with water. In some instances, the whirlpool can throw you back out.

Did you know?

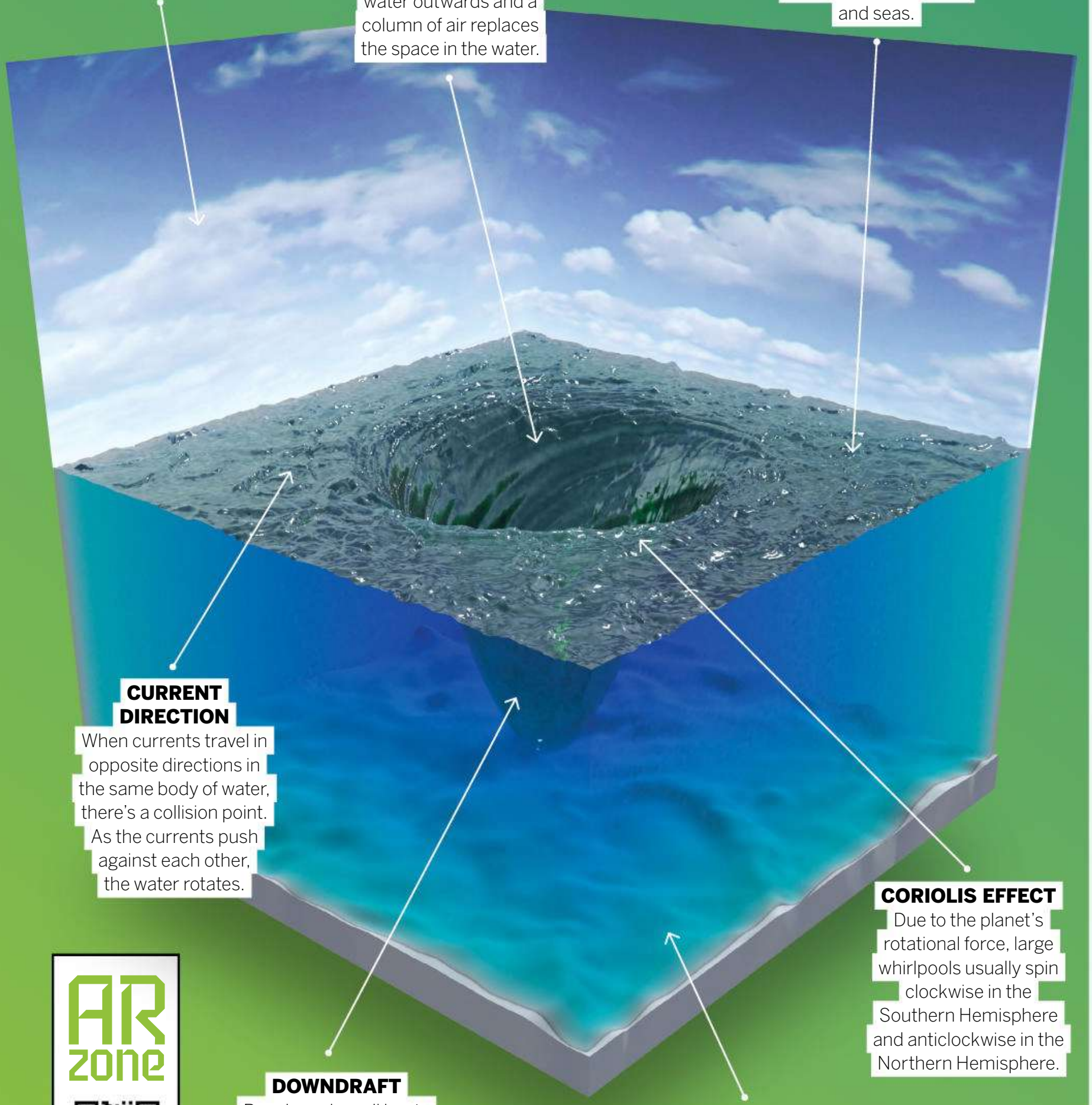
'Maelstrom' combines Dutch verb malen and noun stroom

Corryvreckan whirlpool is located between the islands of Jura and Scarba, Scotland

DID YOU KNOW? Large whirlpools form in the Saltstraumen strait in Norway every six hours

WHAT MAKES A MAELSTROM?

This swirling body of water is caused by clashing currents and uneven terrain



WINDY WEATHER
Strong winds can cause water to travel in different directions.

VORTEX
When a whirlpool spins and accelerates, centrifugal forces push water outwards and a column of air replaces the space in the water.

BODY OF WATER
Whirlpools can occur wherever there is flowing water. This includes creeks, streams, rivers and seas.

CURRENT DIRECTION
When currents travel in opposite directions in the same body of water, there's a collision point. As the currents push against each other, the water rotates.

DOWNDRAFT
People and small boats can be pulled underwater at the centre of whirlpools. This is because gravity provides large whirlpools with a downdraft.

UNEVEN BED
If the seabed is significantly uneven, obstacles can force the water flow to change direction and rotate.

CORIOLIS EFFECT
Due to the planet's rotational force, large whirlpools usually spin clockwise in the Southern Hemisphere and anticlockwise in the Northern Hemisphere.

AR zone

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5 MASSIVE VORTICES

1 SALTSTRAUMEN
In Norway, south of the city of Bodø, a small strait has one of the strongest tidal currents in the world. Where Skjerstad Fjord and Salten Fjord link together, water can travel at ten metres per second to create this giant whirlpool up to ten metres wide and five metres deep.

2 OLD SOW
Formed in the waters between Deer Island and Moose Island in Canada, Old Sow is one of the largest whirlpools in the Western Hemisphere. It can vary in size, within a diameter of 76 metres. Usually several smaller whirlpools surround it.

3 NARUTO
Between Tokushima and Hyōgo in Japan, this tidal whirlpool can form up to 20 metres in diameter. Water enters the narrow Naruto strait at speeds of 12 miles per hour during spring tides.

4 CORRYVRECKAN
Located between two rocks off the west coast of Scotland, this whirlpool is produced by the uneven seabed. Deep pits and basalt pinnacles increase the speed of the water that flows through. It's considered to be the third-largest whirlpool in the world.

5 MOSKSTRAUMEN
In the Norwegian Sea between the island of Mosken and the southern part of the island of Moskenesøya is the second-strongest whirlpool in the world. At its largest it's about 49 metres in diameter.

© Getty / Alamy / Illustration by Adrian Mann

An adult clothes moth (*Tineola bisselliella*)

WHY DO MOTHS EAT CLOTHES?

How these tiny insects can wreak havoc on your wardrobe

WORDS **SCOTT DUTFIELD**

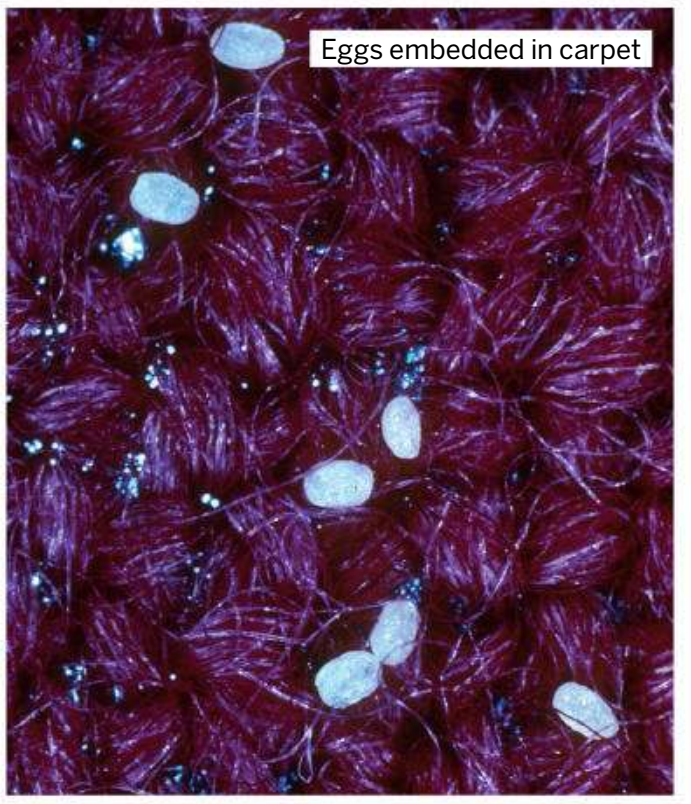
If you've ever pulled out your favourite jumper from the closest and found some unexplained holes in it, then you may have a moth problem. Crawling around in the dark corners of your wardrobe might be one of two species of clothes moth: the webbing clothes moth (*Tineola bisselliella*) or the case-bearing clothes moth (*Tinea pellionella*). These tiny insects have a wingspan of under 20 millimetres, hairy heads and large eyes. The easiest way to tell these moths apart is by looking at the colour of their wings. Webbing clothes moths have a golden sheen to their wings, whereas case-bearing clothes moths are a dull grey-brown colour.

Clothes moths live across the world and can be found in warm, dark and damp areas around your home. These moths have gained a bad reputation for devouring expensive cashmere and woollen jumpers, but it's not the moths that do the damage – it's their offspring. As adults, clothes moths are unable to eat anything. However, their larvae have an insatiable appetite. Clothes moth larvae have evolved a specific diet of a material found in natural fibres such as wool, called keratin. It's the same material that makes up your fingernails and your hair. The clothes moth caterpillars use the keratin to spin silk, which they use to build temporary homes and finally metamorphic cocoons to transform into adult moths.

Did you know?

There are some 160,000 species of moths on Earth

The larvae tuck into keratin-rich fibres, the clothes in our wardrobes, carpets and pretty much any piece of fabric with natural fibres in it that they can find. Their taste for keratin-rich fibres not only poses a threat to fashion and furniture, but also puts the preservation of many historical artefacts at risk. The National Trust identified clothes moths and silverfish (*Lepisma saccharina*) as the most prevalent pests to threaten their collections. The trust has gone as far as trialling the release of microscopic parasitic wasps, along with moth pheromones, to interrupt the moth's life cycle and eradicate the pests.



Eggs embedded in carpet

CARPET CUISINE

Clothes moths aren't the only insects with a taste for carpet fibres. Some of the most prolific carpet grazers come from a group of beetles. Appropriately known as carpet beetles, there are three species that wreak havoc in the UK: the varied carpet beetle (*Anthrenus verbasci*), the black carpet beetle (*Attagenus pellio*) and the brown carpet beetle (*Attagenus smirnovi*).

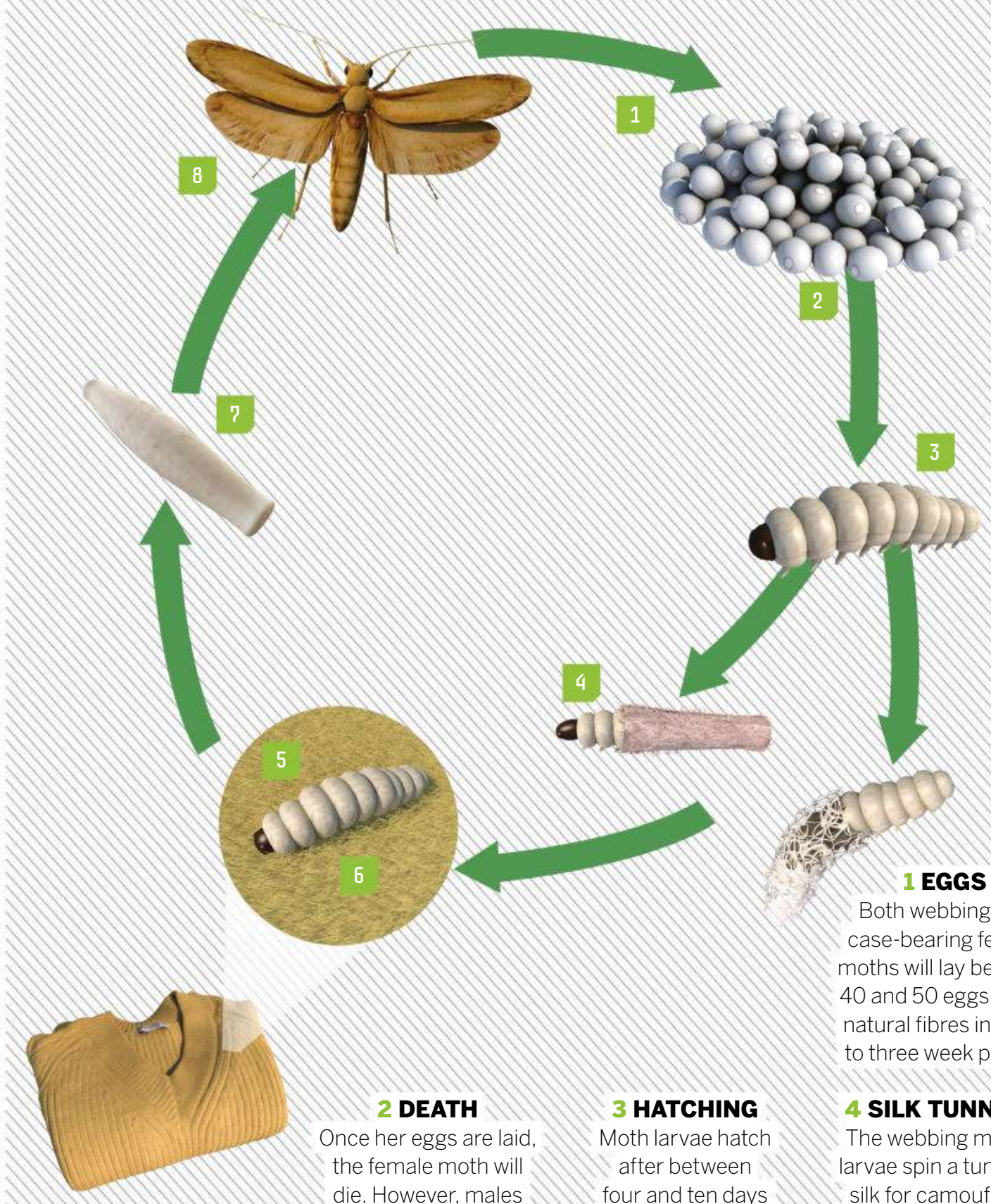
Females lay around 100 white eggs within the carpet, in flooring cracks and on clothing. On a warm summer's day, the eggs will hatch after around 15 days of development. Like clothes moths, it's the larvae of the insects that do all the damage. They too have a taste for wool, although they devour synthetic fibres such as polyester and rayon if they are heavily soiled with food stains. Carpet beetles are rapid breeders, with up to four generations scurrying around at any one time.

The adult varied carpet beetle (*Anthrenus verbasci*), a major pest in the UK

DID YOU KNOW? Evidence on Roman archaeological material suggests they brought clothes moths to Europe

THE LIFE CYCLE OF A CLOTHES MOTH

From egg to adult, how these moths grow up eating your clothes



A larva of the case-bearing clothes moth

1 EGGS
Both webbing and case-bearing female moths will lay between 40 and 50 eggs within natural fibres in a two to three week period.

2 DEATH
Once her eggs are laid, the female moth will die. However, males outlive females, continuing to mate for up to a year.

3 HATCHING
Moth larvae hatch after between four and ten days during the summer months.

4 SILK TUNNELS
The webbing moth's larvae spin a tunnel of silk for camouflage, which they emerge from at night to feed on fibres.

5 CARRY CASE
The larvae of the case-bearing moth do as their name suggests,carrying their silk home around with them while they eat.

6 DEVELOPMENT
Larvae have at least five development stages that cause them to moult over a period of time, which can last between 35 days and two-and-a-half years.

7 METAMORPHOSIS
Once the larval stage is complete, they will create a silken cocoon, and while inside will metamorphosis in adult moths. This process takes between 10 and 50 days.

8 ADULTHOOD
As soon as they emerge from their cocoons, adults will run – not fly – around on fabrics or carpet in a frenzy to find a mate. Females will lay new eggs in one to two days

5 WAYS TO TACKLE MOTHS

1 DEEP CLEAN
Moths enjoy dark undisturbed areas in your wardrobe and drawers. Deep cleaning these areas, along with all the clothes within them, can kill the larvae.

2 FREEZE
Putting clothes that might be home to moth larvae into plastic bags and then the freezer for up to 48 hours should kill larvae.

3 GARMENT BAGS
Store any valuable woollen knits in zip-lock or vacuum-sealed bags to prevent moths from laying their eggs on them.

4 MOTH REPELLENTS
There are a range of products, such as anti-moth paper strips and draw liners, available that work to actively repel moths from laying eggs on your clothes.

5 INVEST IN CEDARWOOD
Clothes moths do not like cedarwood. Simply placing sticks of cedarwood in your wardrobe or investing in cedarwood clothes hangers could help to deter moths.

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This month we're giving you the chance to win a Withings ScanWatch, a hybrid smartwatch that continuously checks your health. The ScanWatch boasts a medical-grade ECG and an oximeter, which both communicate with your smartphone to deliver real-time health information and alert you to any abnormalities. Along with monitoring your vitals while awake, the ScanWatch can also record your sleep performance to give you an overall sleep score

For your chance to win, answer the following question:

There are three main anatomical parts of the brain: the brainstem, cerebellum and _____?

A: CEREBRUM B: AORTA C: BRONCHIOLE

Enter online at **howitworksdaily.com** and one lucky entrant will win!

Terms and Conditions: Competition closes at 00:00 BST on 5 May 2022. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 BST on 05/05/2022. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

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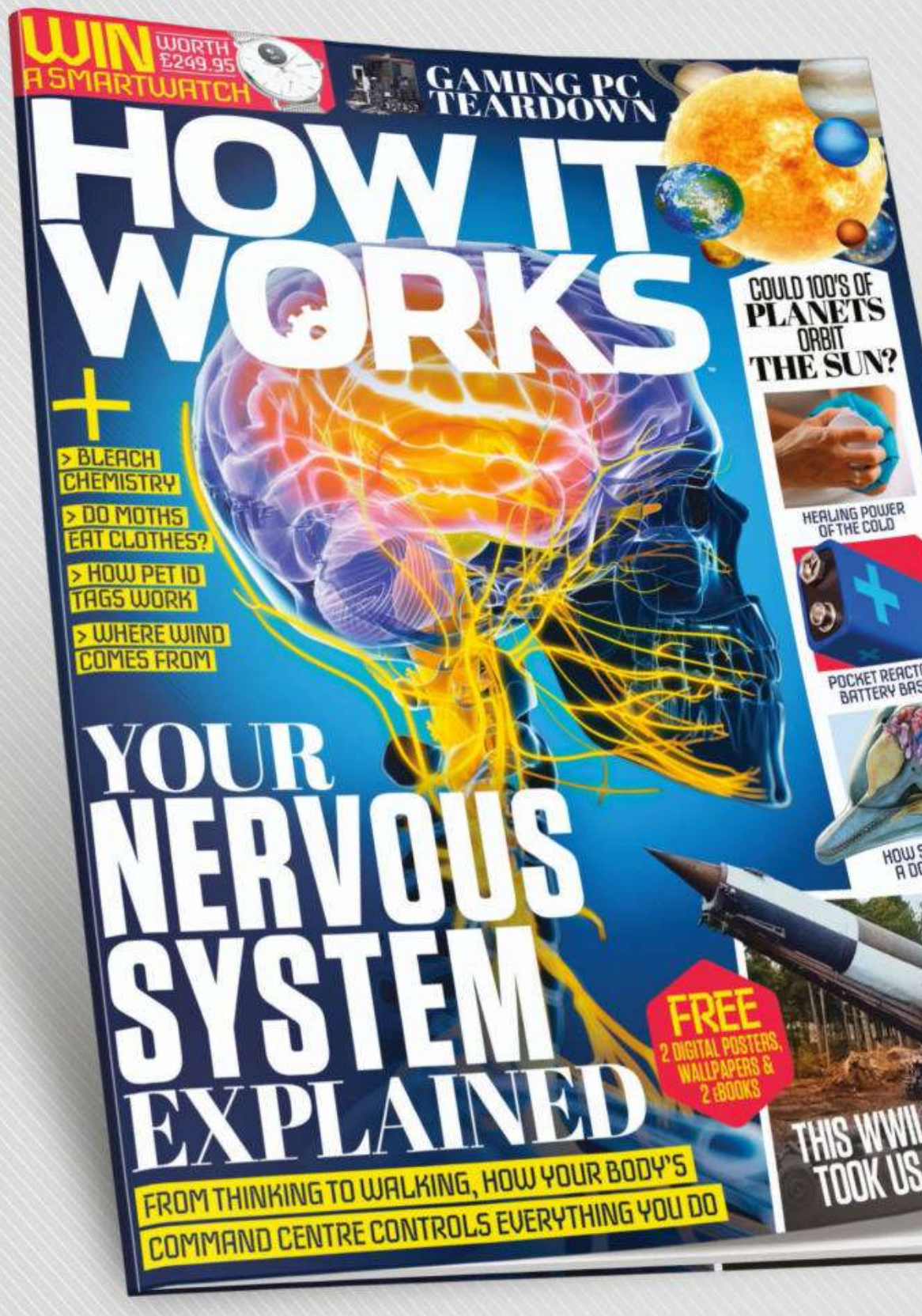
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OFFER EXPIRES **30 JUN 2022**

Did you know?
The Yellow River floods in China have killed millions

Why has flooding become such a problem?

Donald Rempstone

Unfortunately, flooding is simply a part of nature. One in six properties are at risk of flooding in England and Wales. Changes in our climate, such as more severe storms and wetter winters, will increase the risk of flooding in the future. There are a variety of ways to tackle flooding. Changes in land use, such as building houses or putting down concrete, can increase the risk of flooding. Because of this, the UK government's Environment Agency advises against developments that will have an adverse affect on flooding.

When building flood defences, environment agencies look for ways to work with nature rather than against it. Creating mudflats and salt marshes to store flood water can prevent flooding elsewhere, and this can also provide environmental benefits, such as creating new habitats for wildlife.

Individuals and communities also have a role to play in protecting themselves and their properties from flood risk.

DOES A METAL SPOON STOP SPARKLING WINE FROM GOING FLAT?

Mark Blackmore

This is a widespread myth, and has some variations: sometimes the spoon must be silver, but other times the material doesn't matter. It's unlikely that the spoon makes any difference. There's some suggestion that the metal will absorb more heat energy and keep the air in the bottle colder, which may aid the preservation of the sparkle in your wine. The temperature is certainly important though. Colder liquids can hold more gas – in the case of sparkling wines, carbon dioxide (CO_2). This is because the higher the temperature, the more energy the atoms or molecules in the liquid and gas have, making it more likely that the gas molecules can escape the liquid. The lower the temperature, the lower the energy, so less CO_2 can escape. Putting the wine in the fridge is the most beneficial thing if you want to keep your leftover sparkling wine fresh.

Insects breathe very differently to mammals

HOW DO ANTS BREATHE?

Daniel McDermott

Ants, like all insects, don't have lungs, breathing through tiny holes in their sides called spiracles, with one pair per segment. These lead into a network of tiny tubes called tracheae permeating their entire body, getting narrower and narrower, supplying air – and hence oxygen – right to the tissues that use it, rather than using blood to transport it. Though they can open and close their spiracles, they have little ability to pump air in and out, which happens just through general movement. It's this inability that stops insects getting as big as us, with our ultra-efficient lungs and blood.

HOW DO EAR THERMOMETERS WORK?

Kevin Kennedy

These devices are also called tympanic thermometers. This is because they take measurements from the tympanic membrane – the 'drum skin' of your eardrum. Unlike traditional mercury thermometers, which use the expansion of mercury at higher temperatures to measure those in the body, tympanic thermometers measure infrared radiation. Infrared radiation is a form of electromagnetic radiation, like light or radio waves, that is given off by anything that has a temperature.

The probe part of the thermometer is inserted into the ear, where its infrared radiation sensor is within range of the membrane and can get a reading. For hygiene, the probe has a disposable plastic cover which the infrared radiation can pass through, and an extension can be used to place it in the ear of unconscious surgery patients. The reading is much quicker and convenient – just two seconds compared to two minutes for an accurate rectal thermometer reading.

Some people aren't as adverse to smelly socks

Why do humans prefer some smells over others?

Dina Al-Qassar

There are currently two theories for why humans prefer some smells over others. One theory states that we are born with preferences to certain smells. However, another increasingly supported theory suggests that smell preferences are learned. Early in human development, we begin associating certain smells with emotional experiences – smells detected during enjoyable experiences can be perceived as pleasant. Taking this second viewpoint, it's easy to explain how we determine whether smells are dangerous or not: we learn. This has been exploited to ensure easier detection of gas leaks. Gas naturally has no discernible smell. However, a strong smell is added so that when we detect the smell we associate it with danger and can raise the alarm.

© Getty

WHY DOES METAL REACT SO VIOLENTLY IN A MICROWAVE?

Tom Boon

Microwaves are a kind of electromagnetic wave, and as such can create electric currents in metals. Many of the microwaves are actually reflected by the metal and can reflect back onto the magnetron – the part of the oven that produces the microwaves, which can overheat and become damaged. When microwaves hit metal surfaces, free electrons in the metal start to move around; the movement of this charge is how an electric current arises. Some of these electrons will move too much and will actually jump from the metal to the air, which becomes temporarily ionised. This can result in a phenomenon called 'arcing' where an electric spark is produced. Thin metal produces more resistance to an electric current than thick metal, and so can become very hot, even melting.

Did you know?
Microwave ovens were first sold in 1946

How do multivitamins work?

Debbie Green

The human body requires a number of vitamins and minerals to function properly. Examples include vitamin A, which is required by the retina in the eye; vitamin D, which is required for maintaining healthy bones, and vitamin E, which helps form red blood cells. A diet lacking enough essential vitamins is likely to result in vitamin deficiency syndromes. Scurvy, rickets and beriberi are examples of such syndromes. Eating a healthy, balanced diet typically provides enough vitamins for the body's needs. Some people like to take multivitamins to ensure that they receive their required amounts.

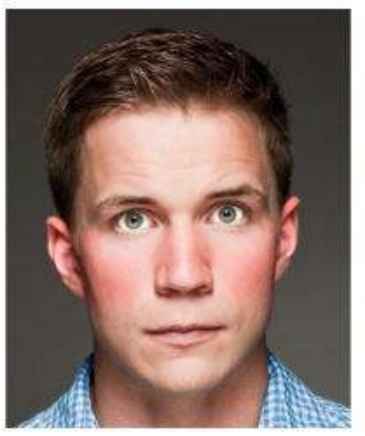
Multivitamins contain a range of different vitamins and minerals, usually including magnesium, zinc, vitamin C and vitamin A in varying amounts. After ingestion the multivitamin's casing is broken down by the gut, the vitamins are absorbed and pass to where they are needed. Care must be taken not to take too many vitamins. In 2004, the Danish government was so worried about people overdosing on vitamins that it banned Kellogg's breakfast cereals that had been enriched with extra vitamins!

The effectiveness of multivitamins is often disputed by scientists. Most experts agree that the best and safest way to ensure that you receive all the vitamins you need is to have a healthy and balanced diet.

HOW DO BONSAI TREES STAY SO SMALL?

Miles Denton

Bonsai is the Japanese art form, but the word is also used to cover any practice of growing very small trees in containers. Unlike dwarf plants, which are genetically small, bonsai uses 'normal' trees and cultivates them to keep them small. The containers in which bonsai trees are grown limit the expansion of their root system and place a cap on the amount of nutrients available to them, limiting their growth above the pot. Rigorous pruning and artificial shaping helps them mimic the shape of much bigger trees, resulting in living miniatures.



WHY DO WE BLUSH?

Toni Baldry

Blushing occurs when an excess of blood flows into the small blood vessels just under the surface of the skin. Facial skin has more capillary loops and vessels, and the vessels are nearer the surface, so blushing is most visible on the cheeks, but may be seen across the whole face. The small muscles in the vessels are controlled by the nervous system.

Blushing can be affected by factors such as heat, illness, medicines, alcohol, spicy foods, allergic reactions and emotions. If you feel guilty, angry, excited or embarrassed, you will involuntarily release adrenaline, which sends the automatic nervous system into overdrive. Your breathing will increase, heart rate quicken, pupils dilate and blood will be redirected from your digestive system to your muscles, and you blush because your blood vessels dilate to improve oxygen flow around the body; this is all to prepare you for a fight-or-flight situation. The psychology of blushing remains elusive; some scientists even believe we have evolved to display our emotions to act as a public apology.

Will the James Webb Space Telescope see clear images of Epsilon Eridani?

Mustafa Maaj

Epsilon Eridani, a star about 10.5 light years away, is of interest to astronomers because observations show that it's surrounded by discs of debris, similar to what the planets and other bodies around our Sun would have formed from. By studying it, we can learn what our Solar System might have looked like in its early days. There are also indications that there may be one or more planets orbiting the star.

The James Webb Space Telescope (JWST), which launched in December 2021, isn't a like-for-like successor to Hubble, as it will mainly operate in the infrared, whereas Hubble concentrates on visible and ultraviolet wavelengths. Infrared is useful for seeing past obscuring dust clouds and to study planets forming. The telescope should have the capability to detect Jupiter-sized planets fairly far from the star, although it won't be able to see sharp images.

It's not yet decided if the JWST will study Epsilon Eridani – astronomers will have to compete for telescope time. But looking at planetary systems is one of the JWST's priorities, so it's a likely target. In 2017, the Stratospheric Observatory for Infrared Astronomy (SOFIA) completed a detailed survey of the Epsilon Eridani system, confirming that it was very similar to our own Solar System. It even included an asteroid belt next to a Jovian planet.

WHAT MAKES DIET COLA DIET?

Douglas Heaton

Diet cola is actually not a modified form of the original cola recipe but is produced from an entirely different recipe. Original cola contains the sugar sucrose or high-fructose corn syrup, depending on the country of origin, which both have a high calorific value. Diet cola, on the other hand, contains a blend of sweeteners – including aspartame and sucralose, which are 200 and 600 times sweeter than regular sugar respectively. This means much smaller quantities of sweeteners can be used to achieve the same level of sugariness without adding lots of calories – a regular can of cola contains around 142 calories compared to just 1.3 calories found in a can of diet cola.

© Getty / Alamy / NASA

Why can ants carry items much heavier than themselves?

Neil Goodchild

The reason that ants can lift so much is due to a concept of physics known as scaling. The muscles of ants are no stronger than human muscles, but it is their small size that provides their advantage. Ants can lift so much because of the ratio between their body size and body mass; their small size means they do not have a large body mass, and the proportion of their mass that is muscle is very high.

As a result they are able to lift weights that are many times larger than their own body weight. In comparison, elephants have massive size and the proportion of their mass that is muscle is quite low. Although they are able to lift incredible weights, they are unable to lift or carry their own body weight. Humans have utilised the laws of physics to our advantage, and we use levers and hydraulics to enable us to lift as capably as ants.

WILL WE CHANGE THE MASS OF THE PLANET BY EXTRACTING ALL THE OIL?

Peter Webber

We are indeed redistributing mass around the planet, but the total stays the same. Earth's mass does slightly change over time due to loss of atmosphere and a gain from meteorites, but it's negligible. If the mass were to considerably increase, our orbital radius around the Sun would decrease, the planet's motion would be faster and a year would be shorter.

However, although Earth's mass isn't changing, redistribution could change the length of a day. Angular momentum is a product of the rate at which an object spins and the distance of its mass from its axis, and the conservation of angular momentum says that it must stay the same at all times. It means that if mass is moved further from the centre of Earth, the rate of rotation must slow down, increasing the length of a day.

Earthquakes shift mass closer to the centre, hence speeding up rotation and shortening the day. NASA states that the huge, magnitude 8.8 Chilean earthquake in 2010 shortened the day by an actual 1.26 microseconds – that's 0.00000126 seconds.

WHO INVENTED THE MOBILE PHONE?

Ken Poole

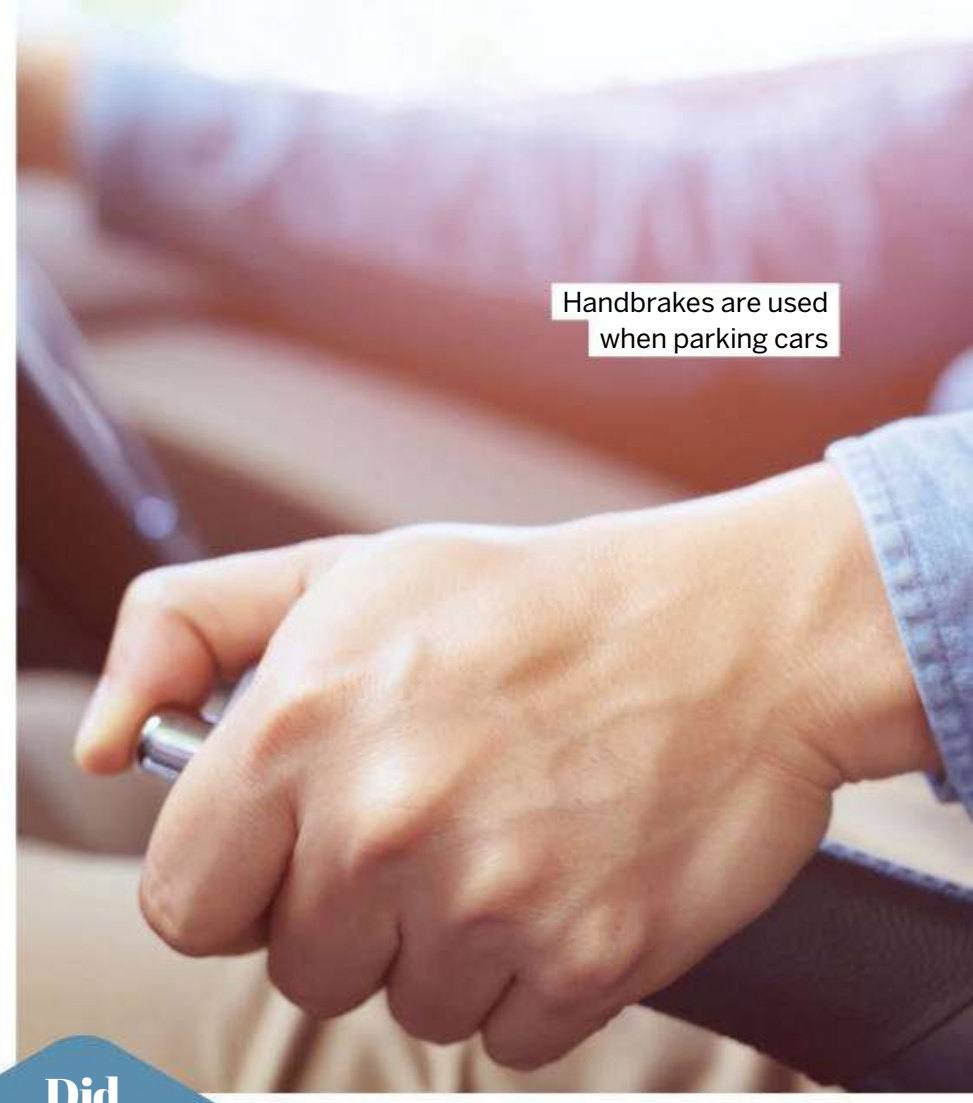
The invention of the first handheld mobile phone is credited to Dr Martin Cooper and his team at Motorola in April 1973. The first call he made was to rival inventor Joel Engel at Bell Laboratories, who had also been racing to invent the first mobile phone. Before this time, radiophones on board ships and in cars were available. However, Cooper's phone was the first truly handheld modern mobile phone. It weighed in at around two kilograms and had a battery life of only 20 minutes. According to Cooper, this didn't matter as you couldn't really hold the phone up for that long!

WHAT DOES A HANDBRAKE ACTUALLY DO?

Gavin Winton

A car's handbrake is the lever to a completely mechanical braking system which will bypass the primary hydraulic system if it fails. When the handbrake is applied, the brake cable passes through an intermediate lever to increase the force of your pull; this force is then split evenly between your brakes by an equaliser.

Typically, a mechanical lever is added to the existing disc or drum brakes on the car. In drum brakes, the handbrake cable runs directly to a lever on the brake shoes. In disc brakes an additional lever and corkscrew is added to the existing calliper piston. When the handbrake is pulled, the lever forces the corkscrew against the piston, which would normally be activated by the hydraulic foot pedal system.



Handbrakes are used when parking cars

Did you know?
Eris is about the same size as Pluto but has more mass

WHY IS PLUTO NOT A PLANET ANYMORE?

Harriet Davis

Since 2006 Pluto has been classified by the International Astronomical Union as a dwarf planet. In recent decades, powerful telescopes have enabled astronomers to discover several Pluto-sized objects beyond Neptune's orbit, and there are probably lots more out there. Either we had to expand the list of planets or it was time to come up with an official definition of what counts as a planet. After some fierce debate, the international committee agreed a condition that a planet must be the biggest thing in its orbital neighbourhood. Pluto and the newly found objects are all in the same neighbourhood, so that rules them out.

Fainting is usually preceded by dizziness

What makes us faint?

Hayley Lewis

Fainting, or 'syncope', is a temporary loss of consciousness due to a lack of oxygen to the brain. It is usually preceded by dizziness, nausea, sweating and blurred vision. The most common cause is overstimulation of the vagus nerve. Possible triggers of this include intense stress and pain, standing up for long periods or exposure to something unpleasant. Severe coughing, exercise and even urinating can sometimes produce a similar response.

Overstimulation of the vagus nerve results in dilation of the body's blood vessels and a reduction of the heart rate. These two changes together mean that the body struggles to pump blood up to the brain against gravity. A lack of blood flow to the brain means there is not enough oxygen for it to function properly, and a fainting episode occurs. Shortly after fainting, blood flow to the brain is restored and the brain functions normally again. Heavy bleeding, diabetes, drugs and low blood pressure can similarly reduce blood flow to the brain, causing a lack of oxygen and fainting.

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The latest book releases for curious minds

THE LITTLE BOOK OF SPACE

A SMALL BOOK FOR A VERY BIG TOPIC

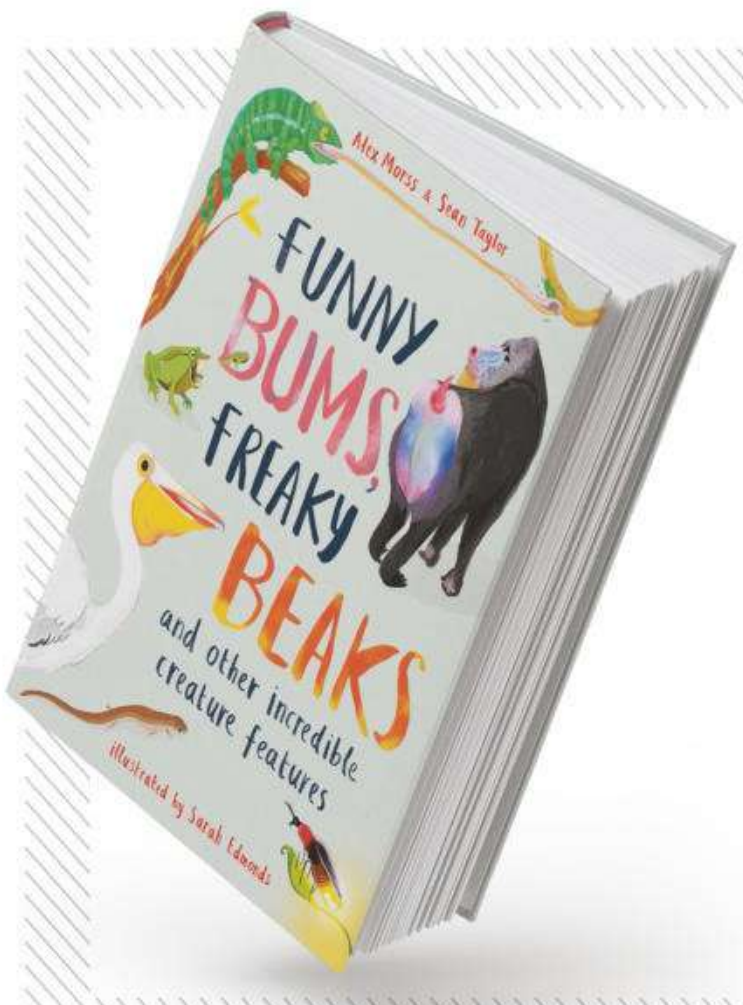
AUTHOR **NORMAN FERGUSON**
PUBLISHER **OCTOPUS PUBLISHING GROUP**
PRICE **£6.99 (APPROX. $9.20)**
RELEASE **OUT NOW**

We're already off to a good start with a fan-favourite quote by the famous author of arguably the best-known science-fiction book of all time: "Space is big. Really big. You won't believe how vastly, hugely, mind-bogglingly big it is." Douglas Adams of *A Hitchhiker's Guide to the Galaxy* fame is a master of understatement, even in these short, superlative-packed sentences, but he was writing a work of fiction.

The Little Book of Space author Norman Ferguson has given himself the job of conveying the true vastness of space and its associated sciences, then distilling this down for a younger audience who haven't been steeped in several decades of television series hosted by the likes of Brian Cox, Patrick Moore and Carl Sagan, who is also quoted in this book. When you think about it, it's quite the task Norman has set himself, but he makes it feel effortless. Beginning with the most familiar objects in the night sky, the reader is taken on a whistlestop tour of the Solar System, from the Moon out to Pluto and anything significant in between, including major features of the planets and other celestial objects, punctuated by quotes from big-shot scientists and pop-culture icons.

We're given a gentle guide to astronomy, the Big Bang theory, how stars are born and die across the billion-year history of the universe, space technology, the future of space exploration and even space in the arts – a kind of list of what you need to watch, read and listen to first if you're going to embrace one of the broadest of all the sciences. We haven't checked everything off that list ourselves, and we can imagine it might be a little overwhelming for a reader who's new to it all. But though the subject is huge beyond even the imagination of a child, *The Little Book of Space* is an easy read – and as a reference book a younger generation can turn to, it's invaluable.

The reader is taken on a whistlestop tour of the Solar System



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From strange tails to peculiar tongues, discover the weird and wonderful features the world's wildlife have grown. What's great about this is the breadth of animals that are included.

It's all too easy to stick to the animals children might see in a zoo. But this book is packed with creature features you're not used to, such as the inflatable necks of great frigatebirds, planthopper parachutes and the fin-like ears of dumbo octopuses. An adult reading at bedtime may also learn something new for themselves, such as the fact that blue iguanas have a third eye on top of their head to spot predators. Packed full of vibrant illustrations, any child will be hard-pressed to keep their eyes away from the pages. *Funny Bums, Freaky Beaks* is great to sit down and thumb through with a youngster or to dip into and discover something new about wildlife every day.

THE ASTRONOMER WHO QUESTIONED EVERYTHING

THE STORY OF ASPIRING SPACEWATCHER MARIA MITCHELL

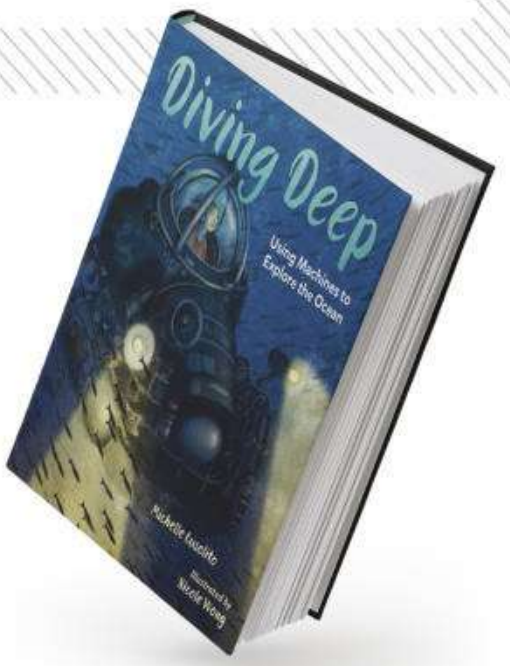
AUTHOR **LAURA ALARY**
ILLUSTRATOR **ELLEN ROONEY**
PUBLISHER **KIDS CAN PRESS**
PRICE **£15.99 / $18.99**
RELEASE **5 MAY**

In the early 1800s, a young girl called Maria Mitchell from Nantucket spent her days exploring the beach for seashells and gazing up at the stars with her astronomer and mathematician father. Teaching her everything he knew, Maria set her sights on the night sky, eventually becoming the first female astronomer in the US and the first-ever American scientist to discover a comet. Unfortunately, not many people know Maria's inspirational story, but they can discover it in this charming children's book. From an inquisitive youth to pioneering scientist and the first female astronomy professor, this book takes its young audience through Maria's life story and how she became one of the most important women in astronomy. Along with the biography of Maria Mitchell, *The Astronomer Who Questioned Everything* tells the story of how perseverance in the face of adversity and dedication to your passions can lead to remarkable things. Everything about this book is brilliant. From its wonderful illustrations to its engaging narrative, it's the perfect evening read with your children.

DIVING DEEP

USING MACHINES TO EXPLORE THE OCEAN

AUTHOR **MICHELLE CUSOLITO**
ILLUSTRATOR **NICOLE WONG**
PUBLISHER **CHARLESBRIDGE**
PRICE **£14.99 / $17.99**
RELEASE **14 JUNE**



From scuba diving near the surface to deep-diving submersibles thousands of metres below, this book explores the technology available for deep-sea exploration. Filled with lively illustrations on every page – and diagrams to map out different depths – this book's artwork manages to shine light and vibrance into the darkest parts of the ocean.

We're told not just about some of the creatures that can be observed in different ocean habitats, but the wide variety of methods that humans use to connect with marine life. And while freedivers train their bodies to remain without oxygen or equipment for long periods of time, there are also machines designed to expertly navigate these waters. This book displays the impressive techniques associated with each method.

Diving Deep is an appropriate read for children between the ages of around five and eight. Within this age range, some readers will be unaware that scuba diving, or walking on the ocean floor, is possible. For others, this book is sure to provide new information about how each piece of apparatus operates and what they can achieve. *Diving Deep* is a brilliant introduction to the many varied ocean ecosystems and a reminder of how much life is unseen. Deep-sea missions are dangerous, as explained in the text, yet explorers still pursue the unknown. The author ends by answering the question of why: we dive deep to uncover the secrets of our oceans, and this book is the perfect first step for young readers to do so themselves.

RACING GREEN

HOW MOTORSPORT SCIENCE CAN SAVE THE WORLD

AUTHOR **KIT CHAPMAN**
PUBLISHER **BLOOMSBURY**
PRICE **£20 / $30**
RELEASE **OUT NOW**

Motorsport has succeeded in capturing the attention of the world. Many millions watch as vehicles designed to set speed records battle fearlessly around the track. But how has technology changed to not only improve the entertainment value, but the safety of the sports' drivers and the health of the planet as a whole?

At the beginning of *Racing Green*, the reader is introduced to Romain Grosjean, a Swiss-French racing driver who was engulfed by flames during the 2020 Bahrain Grand Prix, but exited his vehicle alive. Thanks to innovations in motor-racing technology, his life was saved three times during the impact alone. Author Kit Chapman explains how technology in this sport is scrutinised after every accident or fatality to save others, including Grosjean, from death.

Just like a motor race, the narrative of this book covers vast ground, unexpected twists and a sense of hope about what's next to come. The latter is highlighted by the emergence of autonomous tech, electric vehicles, biofuels and other renewable fuels that are being incorporated gradually into the sport. Science journalist Chapman's captivating storytelling recounts the most amazing events and tales from the history of motorsport, with the ability to fascinate both fans and those interested in the science and technology behind it. Combining major historical milestones with exclusive interviews, *Driving Green* serves as a reminder of how this much loved sport continues to advance and improve.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

			8		6		4	1
5					4			6
7	4	6		1	3			
	1					4	7	
4	6		3		9	5		2
2		9	1		7		6	
6		8	4	9		2		3
				7	8			
1	9	4		3	2	6		

MEDIUM

	6					3	7	9
			7					
1	7		8			2		
	9		1	4	6			5
2		7						3
	4	6	2		7			1
6		4			9			
	2	3		1	4		9	
				7			4	2

HARD

			1	9				
2						5	8	
		4	2					
			4	5	9	2		
	1	2				6		4
		3	6	2			7	8
6								
				7				2
5	8			6				

Word search

Find the following words

NERVES
COLD
BATTERY
SAIL
GEARS
ROCKET
DOLPHIN
MOTH
GOLDILOCKS
WIND
COMPUTER
BLEACH

N	O	L	A	I	Z	E	A	C	O	N	P	E	D	W
E	P	G	A	R	V	D	O	L	P	H	I	N	V	I
R	E	F	O	G	H	C	T	S	A	N	B	K	L	N
V	C	M	Y	L	I	J	O	C	K	S	G	E	A	D
E	O	G	O	I	D	L	B	I	P	H	E	N	D	A
S	A	I	L	A	W	I	D	L	O	M	A	I	L	U
N	L	E	R	J	H	V	L	G	O	D	R	L	T	X
Z	D	O	K	C	E	O	R	O	S	T	S	I	E	V
C	I	M	C	O	L	D	P	L	C	M	O	T	K	H
B	A	C	O	M	P	U	T	E	R	I	Z	M	C	P
R	O	C	H	E	I	L	H	C	A	E	S	R	O	N
Y	K	T	F	I	B	E	L	H	O	M	C	K	R	U
C	O	L	M	O	N	E	D	C	S	T	N	E	R	B
M	O	T	Y	R	E	T	T	A	B	I	N	D	O	K
S	L	P	E	M	P	L	B	L	E	A	C	H	E	H

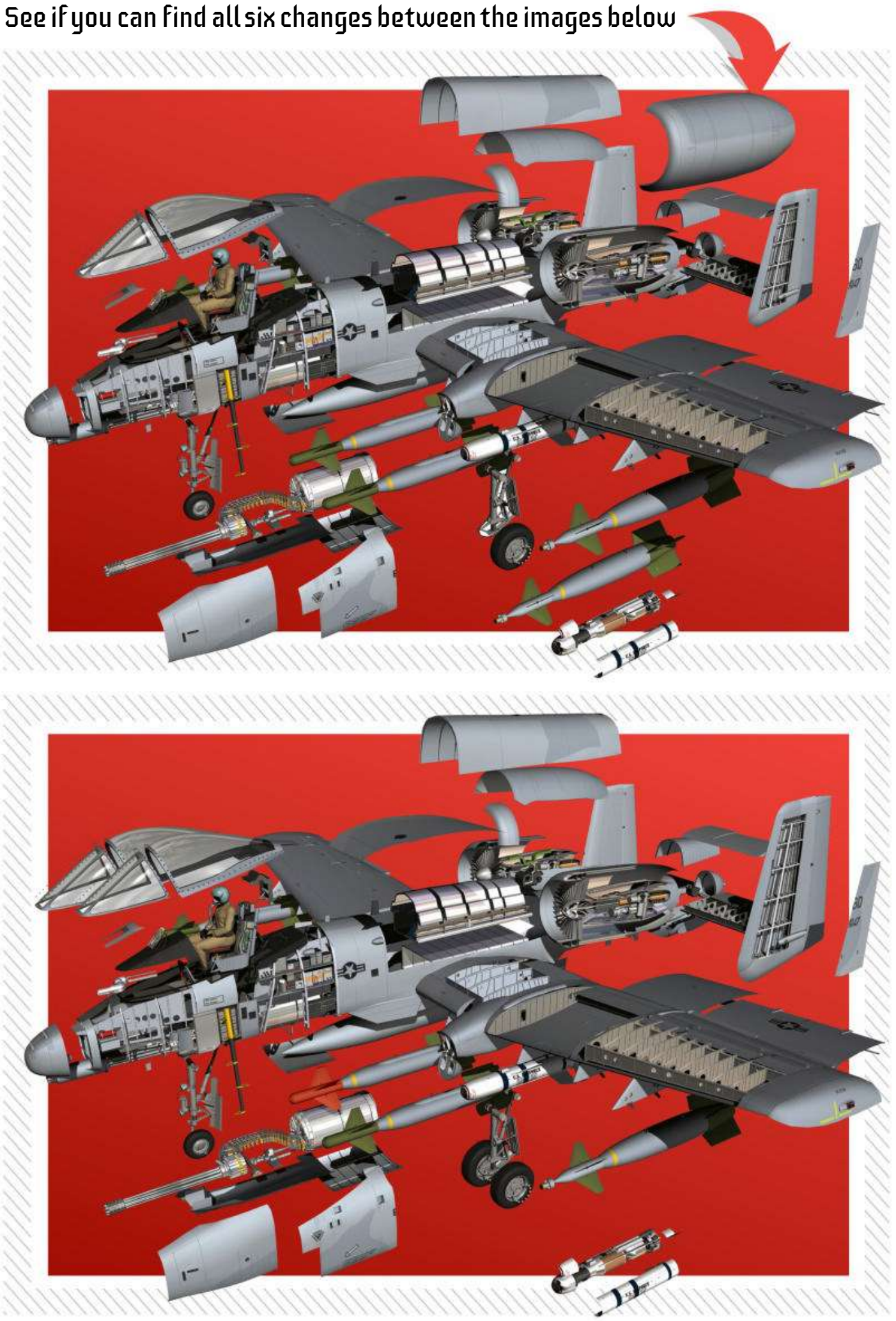
What is it?

Hint: These tiny drops often appear in the morning

A

Spot the difference

See if you can find all six changes between the images below



QUICKFIRE QUESTIONS

Q1 What force resists motion between two objects?

- Inertia
- Gravity
- Centrifugal
- Friction

Q2 Who was the first woman to win a physics Nobel Prize?

- Rosalind Franklin
- Marie Curie
- Katherine Johnson
- Ada Lovelace

Q3 Which of these instruments measures air pressure?

- Thermometer
- Geiger counter
- Barometer
- Rheostat

Q4 What colour is human blood when it's deoxygenated

- Blue
- Red
- Green
- White

Q5 Which of these does a larva eventually turn into?

- Oak tree
- Dragonfly
- Earthworm
- Volcano

Q6 Which of these organs is also a muscle?

- Brain
- Liver
- Lungs
- Heart

Answers

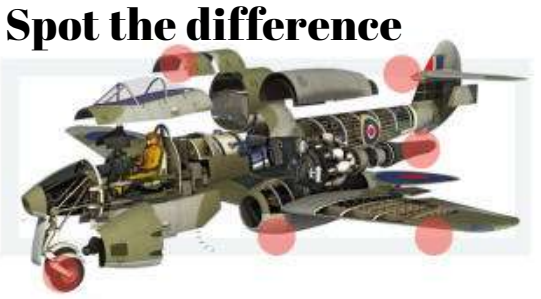
Find the solutions to last issue's puzzle pages

Q1 4 BILLION TONNES
Q2 COCKROACH
Q3 110,000 MILES
Q4 OCTOPUS
Q5 SEVEN
Q6 CARBON DIOXIDE

What is it?

ORANGE

Spot the difference



© Getty

MAKE AND EXCAVATE YOUR OWN SPONGE FOSSIL

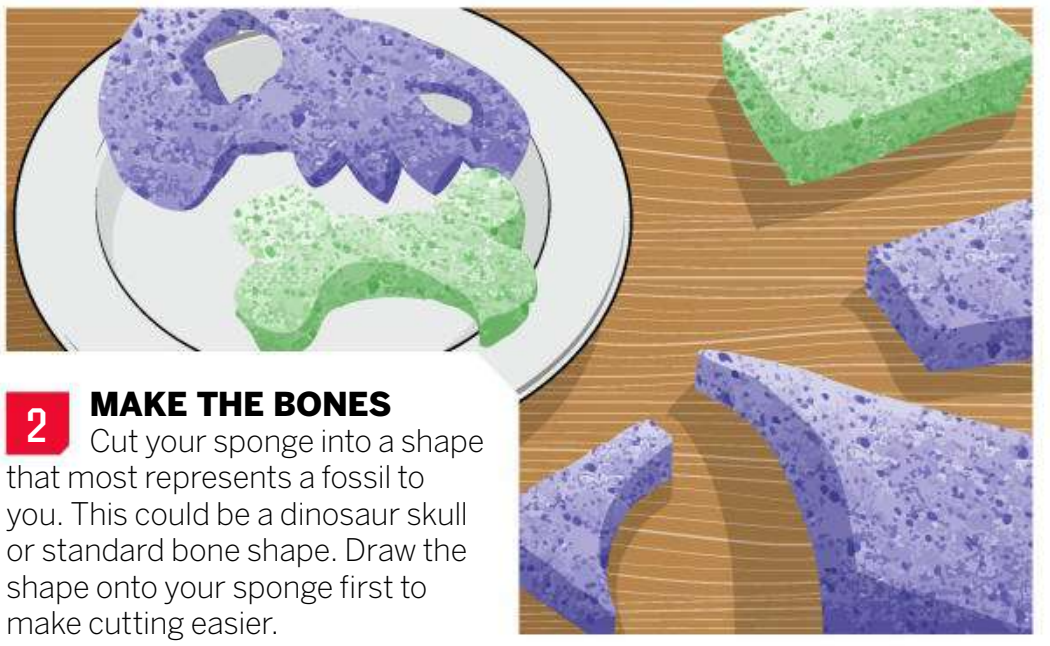
Discover how fossils form by permineralisation as you dig up homemade bones

KIT LIST

- One large, clean sponge per fossil
- A large plastic container
- Enough sand to fill your container
- Water
- Salt
- Scissors
- Paintbrush or other small brush

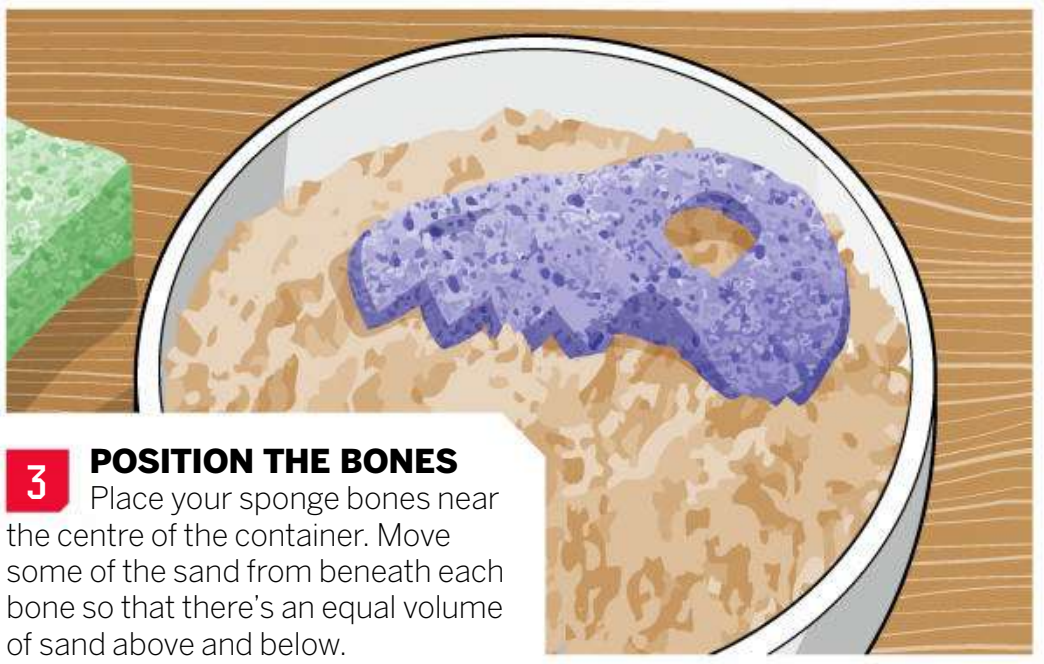
1 COLLECT THE SAND

For this experiment, you'll need enough dry sand to fill your plastic container. When the sponge is placed in the container there should be about two centimetres of sand above and below it.



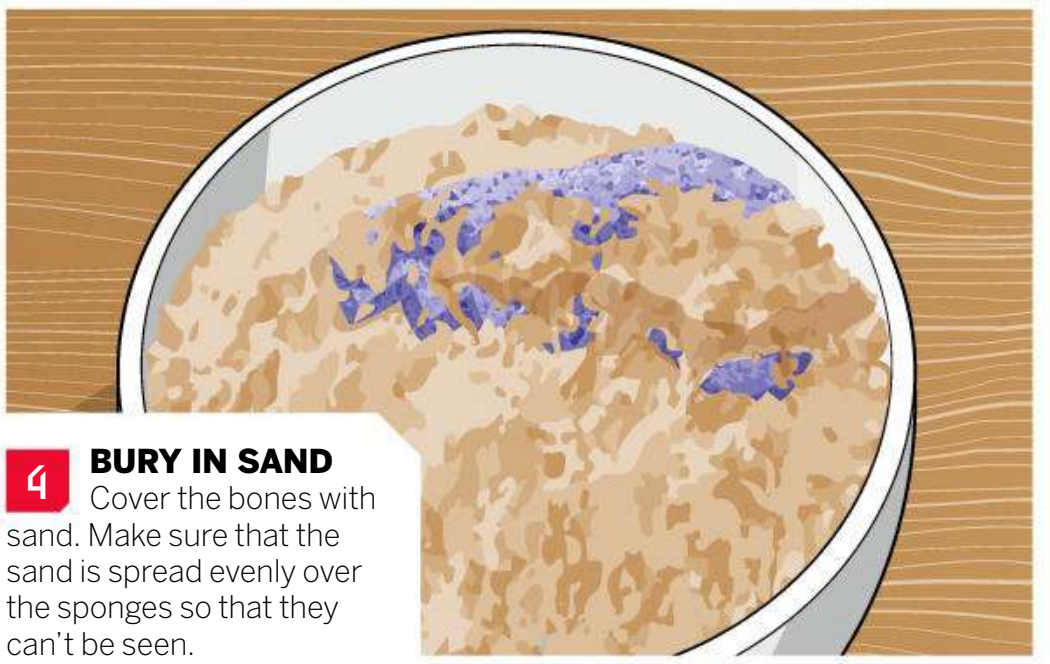
2 MAKE THE BONES

Cut your sponge into a shape that most represents a fossil to you. This could be a dinosaur skull or standard bone shape. Draw the shape onto your sponge first to make cutting easier.



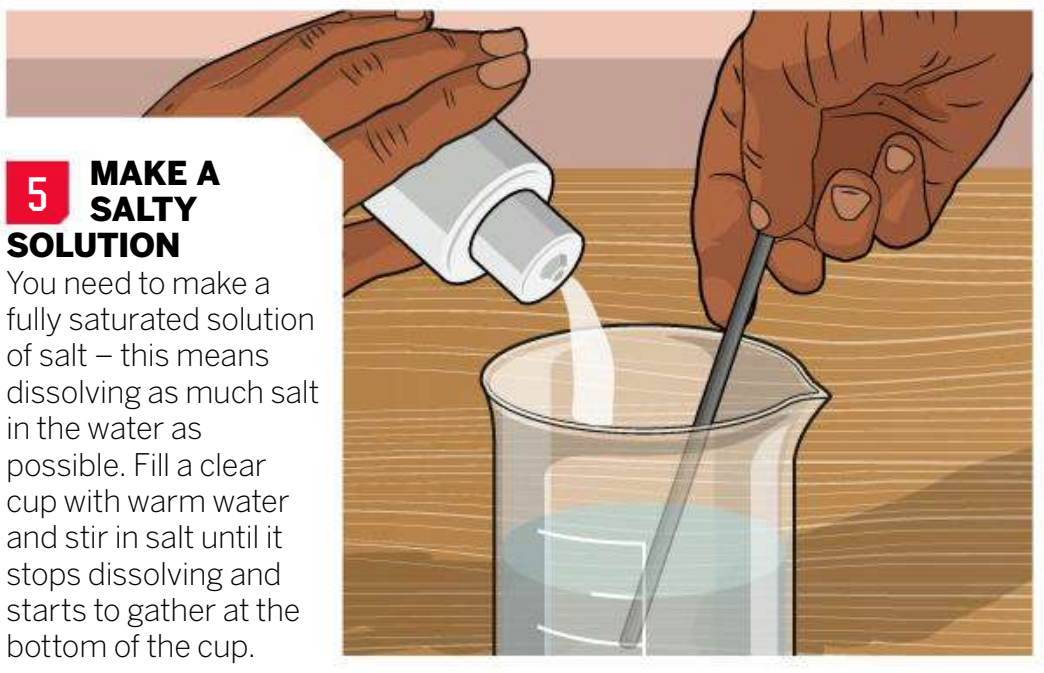
3 POSITION THE BONES

Place your sponge bones near the centre of the container. Move some of the sand from beneath each bone so that there's an equal volume of sand above and below.



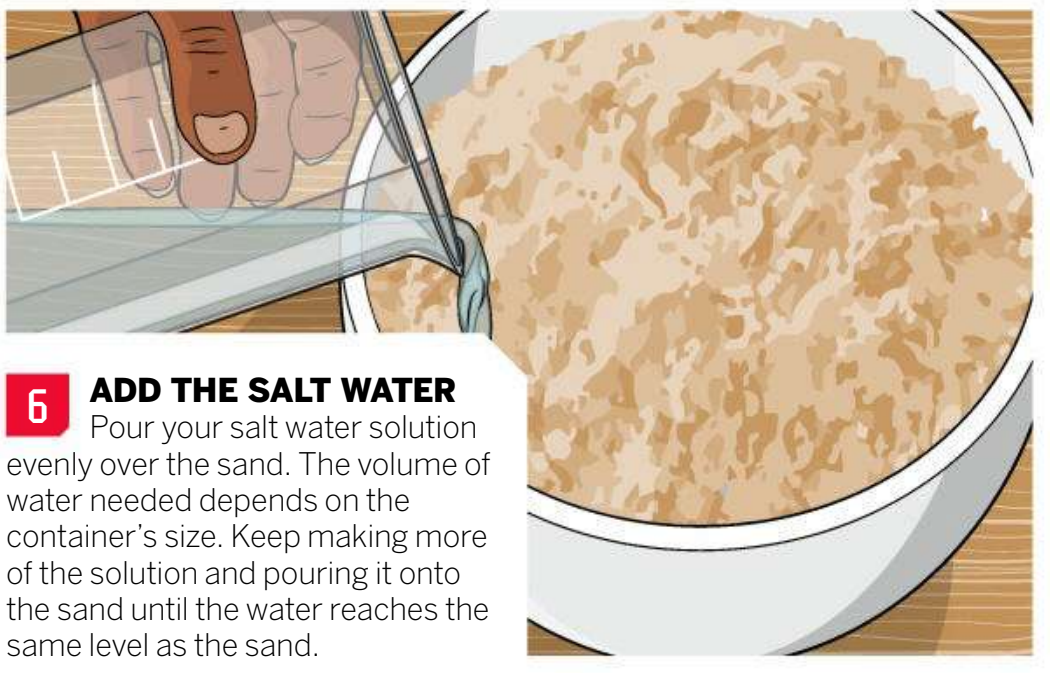
4 BURY IN SAND

Cover the bones with sand. Make sure that the sand is spread evenly over the sponges so that they can't be seen.



5 MAKE A SALTY SOLUTION

You need to make a fully saturated solution of salt – this means dissolving as much salt in the water as possible. Fill a clear cup with warm water and stir in salt until it stops dissolving and starts to gather at the bottom of the cup.



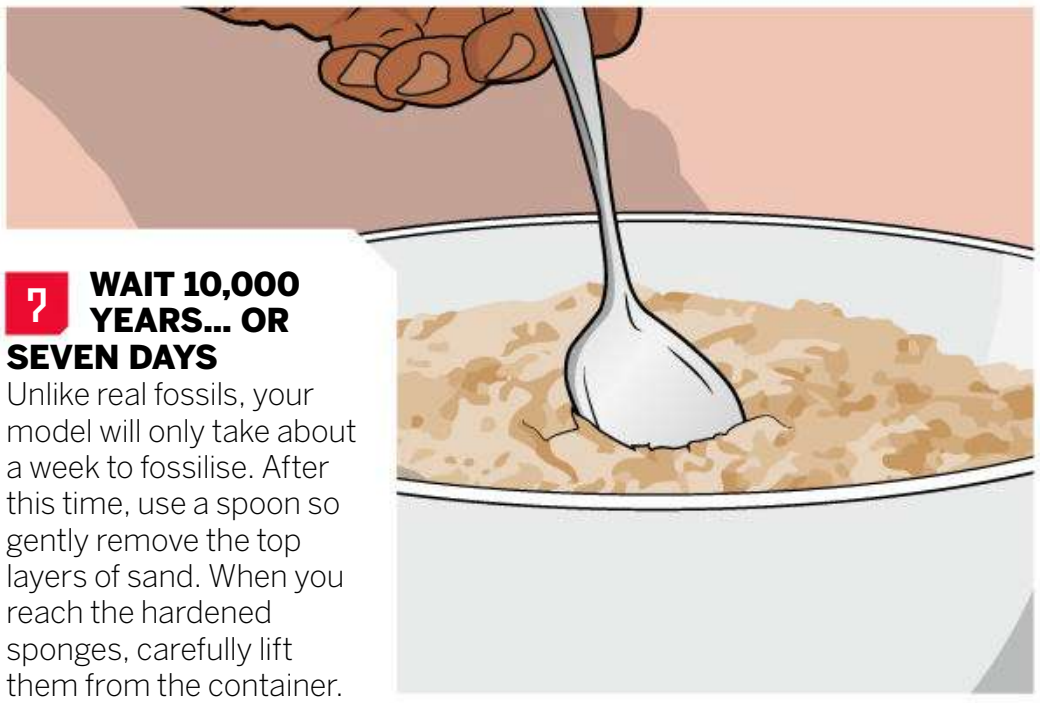
6 ADD THE SALT WATER

Pour your salt water solution evenly over the sand. The volume of water needed depends on the container's size. Keep making more of the solution and pouring it onto the sand until the water reaches the same level as the sand.

NEXT ISSUE
MAKE YOUR DRAWING DISAPPEAR WITH A REFRACTION MAGIC TRICK

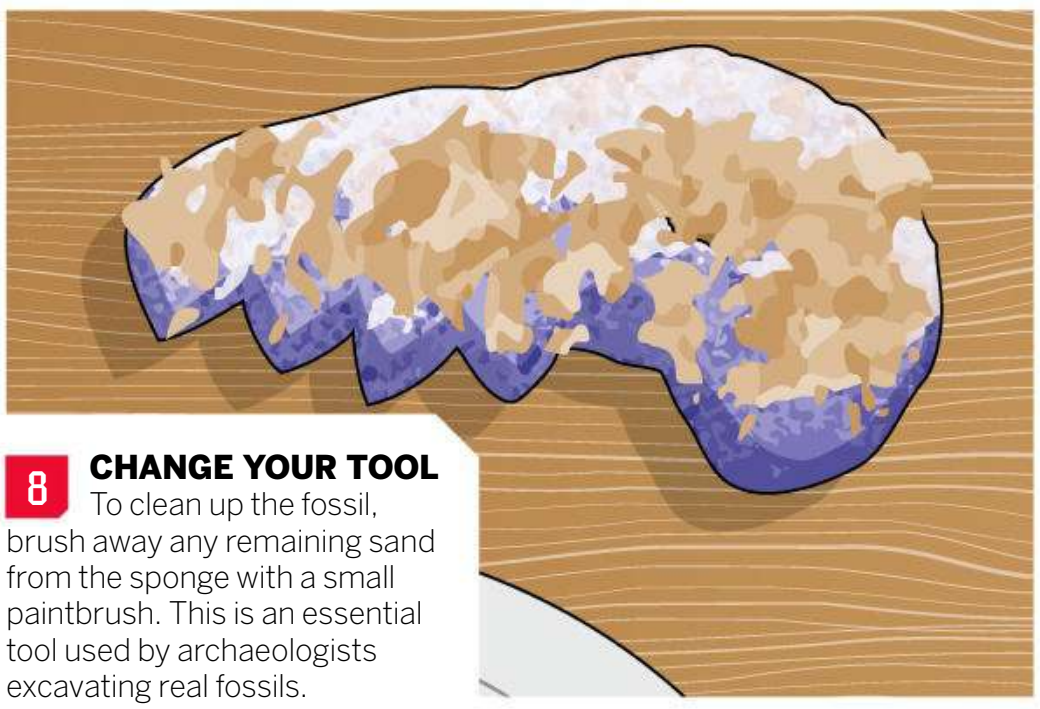
DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you



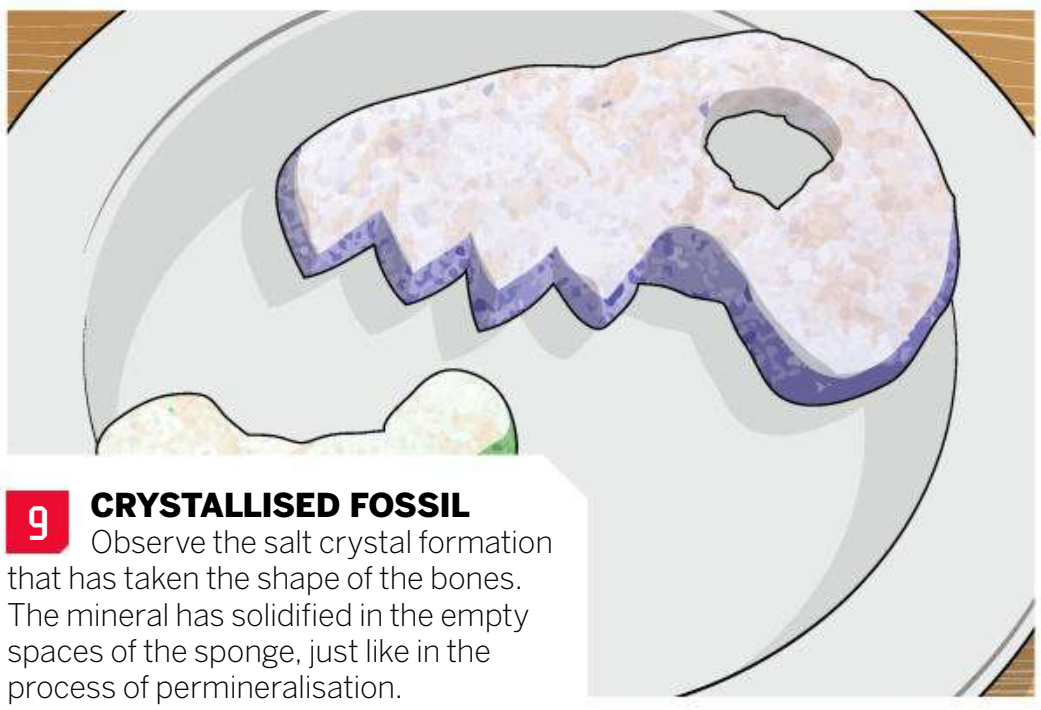
7 WAIT 10,000 YEARS... OR SEVEN DAYS

Unlike real fossils, your model will only take about a week to fossilise. After this time, use a spoon so gently remove the top layers of sand. When you reach the hardened sponges, carefully lift them from the container.



8 CHANGE YOUR TOOL

To clean up the fossil, brush away any remaining sand from the sponge with a small paintbrush. This is an essential tool used by archaeologists excavating real fossils.



9 CRYSTALLISED FOSSIL

Observe the salt crystal formation that has taken the shape of the bones. The mineral has solidified in the empty spaces of the sponge, just like in the process of permineralisation.

SUMMARY

This experiment models the fossilisation of extinct animals. In most cases, fossilisation takes place in the hardest parts of the body, such as the bones. While soft tissue decomposes relatively soon after death, bones can survive long enough to be buried by sediment. This sediment hardens over time to form sedimentary rock. If water is able to seep through cracks in the rock and reach the buried bone, the bone can be dissolved by the water over the course of many thousands of years. Minerals that are being carried by the water are deposited in the empty spaces left by the dissolved bone, taking its shape in a process called permineralisation. In this experiment, salt serves as this mineral, but in reality a fossil is likely to be made up of many different minerals. Seven days isn't long enough to see the entire sponge dissolve away, but this process models how minerals can take the shape of a fossil.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media

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INBOX

Speak your mind

MODERN MAMMOTHS

LETTER of the MONTH

Dear **HIW**,
What are the chances of bringing back extinct animals like the woolly mammoth. Would they be able to adapt to today's world?
Conor Cartmill, age 12

There are many who'd like to see the return of extinct animals, but bringing them back in full isn't currently possible. Scientists are currently working to bring animals that vanished from Earth long ago back into our lives. By editing the genetic code in the DNA of extinct animals' closest living relatives, they can slowly build backwards and manipulate a model of an extinct creature's DNA. Using this method, scientists can make animals that closely resemble extinct animals, but they wouldn't be the same.

One of the highest profile cases involves the woolly mammoth you mentioned, which died out around 4,000 years ago.

Woolly mammoths are extinct, but some of their DNA has been preserved

Their DNA is preserved in the frozen soil of Siberia, so some scientists are working on a project to combine fragments of genetic code obtained from these frozen samples with that of living elephants. There might be thousands of years separating these two species, but if they are successful in combining them, this could be the closest scientists can come to bringing back woolly mammoths.

Animals are continually adapting to fit changing climates and environments. As these extinct species are being combined with animals that live today, they hold a higher chance of survival in the modern world than their real woolly mammoth ancestors would.

AI EYES

Dear **HIW**,
Is it the human retina that can detect biological age and can predict death age using some sort of AI technology?
Shathis Waran

Researchers used artificial intelligence on retinal imaging scans to work out their biological age. The biological age of the retina and a person's actual age can be compared to work out someone's 'retinal age gap'. If this biological age is higher, it could indicate that the body is ageing faster in general and that death is more imminent than in someone the same age with a smaller gap.

The artificial intelligence used in this particular study put this theory to the test; the results found that a one-year increase in retinal age gap was linked to a two per cent increase in risk of death.

The retina is a thin tissue that lines the back of your eye

This technology is in the early stages of testing, and while a pattern was found, the researchers recognised that statistics vary based on different causes of death, so this cannot be accurately used to predict someone's 'death age'. Even so, it's interesting that your eyes can be used to provide some of these answers.

WIN!

AN AMAZING PRIZE FOR LETTER OF THE MONTH

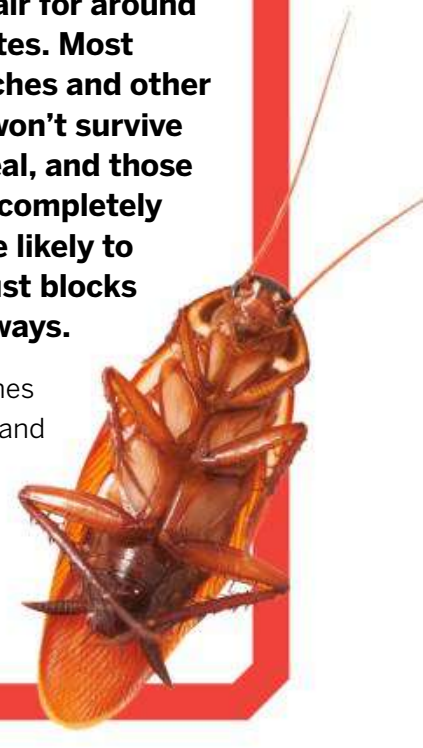
THE LITTLE BOOK OF SPACE

An informative and engaging guide to the wonders of the universe that will fascinate readers of all ages.

TOUGH INSECTS

Dear **HIW**,
Cockroaches are said to be tough, but can they survive being sucked into a vacuum cleaner which is left running for a few minutes? How about other creatures like spiders?
Stephen

We don't recommend trying this out, but there is research that suggests that some cockroaches can survive being sucked into a vacuum cleaner and can remain alive without air for around 40 minutes. Most cockroaches and other insects won't survive this ordeal, and those that get completely stuck are likely to die as dust blocks their airways.



Cockroaches can withstand pressures 900 times their own body weight

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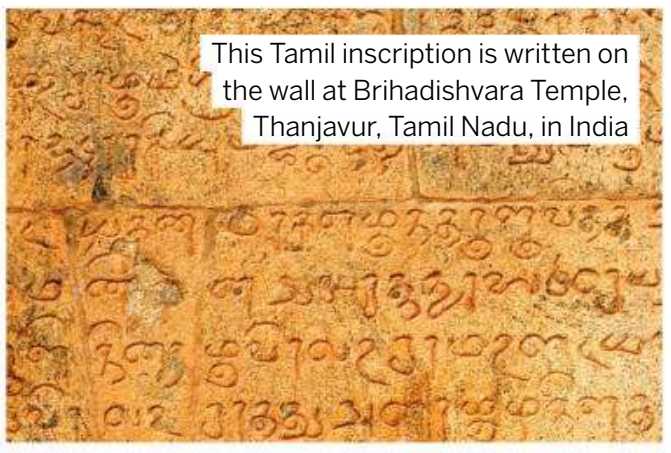
Minerals can build up in the bottom of a kettle

KETTLE CHEMISTRY

Dear **HIW**,
I keep finding white bits floating in the water after the kettle boils. Is this to do with the chemistry of the water being boiled? Is there a way to stop this from happening?
Megan Richardson

If the white substance is chalky and accumulates mostly at the bottom of your kettle, it's limescale. You're right to suspect the water's chemistry, as people living in places with 'hard water' are most likely to discover this in their kettles. Hard water is more alkaline and has a higher mineral content. Limescale is a result of high concentrations of magnesium and calcium in the water. As water boils and evaporates, the solid minerals are left behind. There's no way to completely stop limescale buildup if you use hard water, but there are many kettle cleaners that target limescale.



This Tamil inscription is written on the wall at Brihadishvara Temple, Thanjavur, Tamil Nadu, in India

HISTORY OF LANGUAGE

Dear **HIW**,
Of all the languages that exist today, which one is the oldest?
Elaine Gaddie

Tamil is considered to be the oldest language still in use by people today. Tamil has been spoken for at least 5,000 years, and today is spoken across India, Sri Lanka, Singapore and Malaysia. While you may have heard of many of the world's languages, you are unlikely to have heard of them all. There are around 6,809 languages spoken in total worldwide but only between 150 and 200 languages that are spoken by over a million people.

WE ASKED YOU

This month on Instagram, we asked you: Which animals do you think are the most clever?

@AMSIMANN
Dolphin

@SCIMAXFACTS
I think that dolphins are the cleverest creature

@EILLAZUL
Rats

@AESTHETICALLY_AJ
Pigs' intelligence is overlooked. One study showed that they can use technology and play video games

@GRANT_SHELDON
Orangutans! They can play charades

@CYRUSTHEVIRUS_YEET
Humans

@VIRGINIA_WINSLET
Dogs

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FAST FACTS

Amazing trivia that will blow your mind

11 MILLION

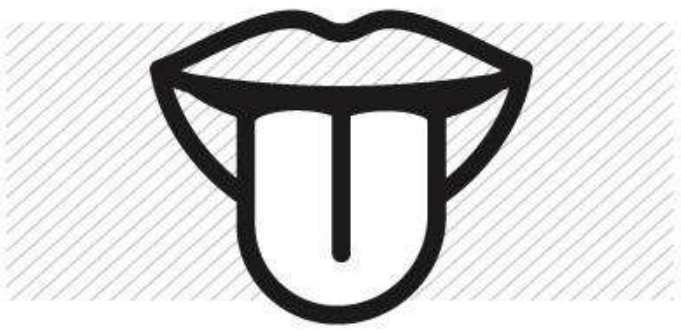
Our brains process millions of bits of data per second

100,000

A single bolt of lightning could cook this many pieces of toast

200 million

The number of virus particles that a single cough can contain



OUR SALIVA CONTAINS A POWERFUL PAINKILLER CALLED OPIORPHIN

900

Human skin replaces itself hundreds of times in an average lifetime

If you drove a car straight up, it would take an hour to get to space

36

A wren can sing a staggering number of notes in just one second

4500 BCE

Evidence of horse riding dates back to over 6,500 years ago

IN LIQUID AND SOLID FORMS, OXYGEN IS PALE BLUE

1828

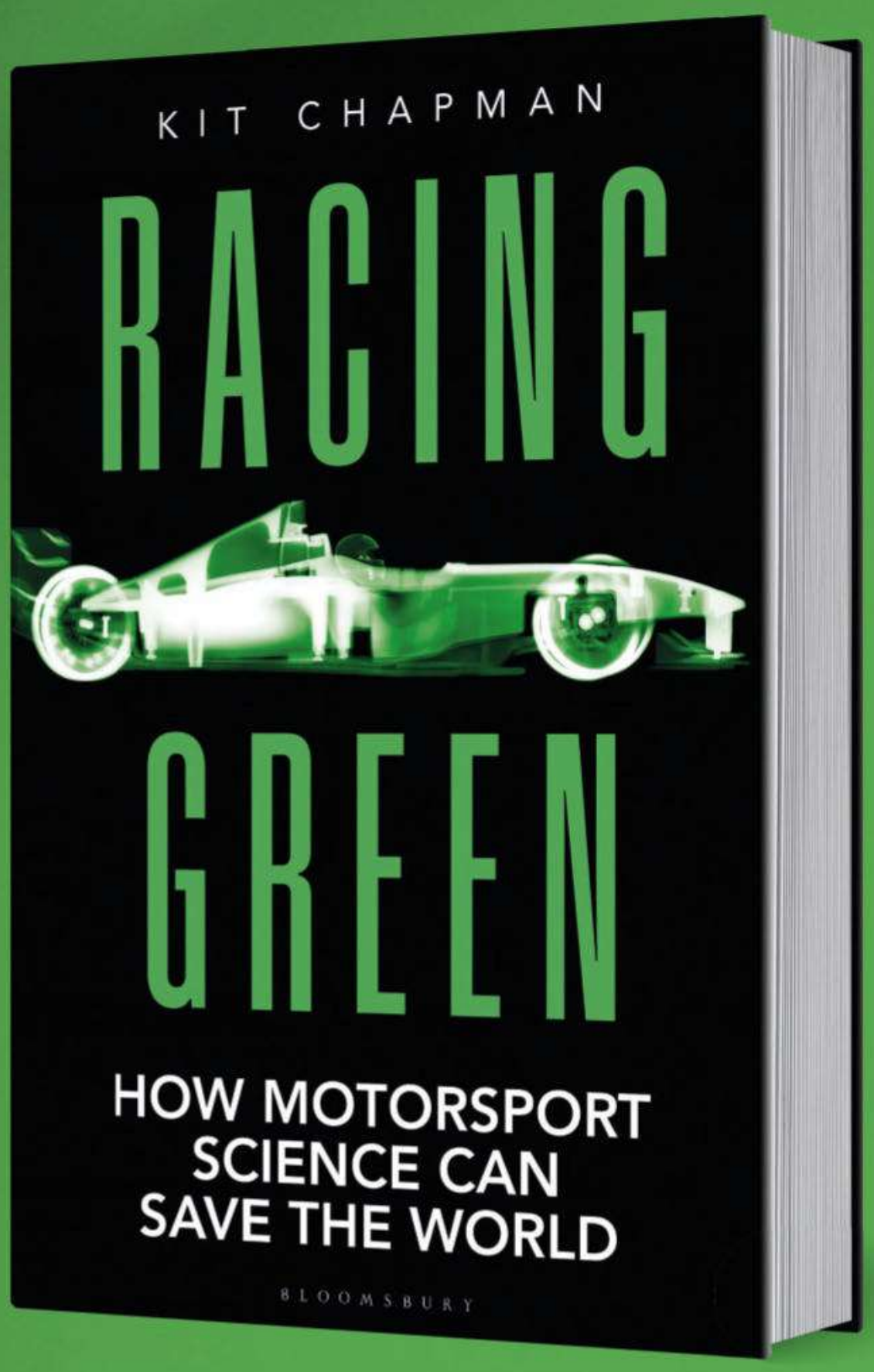
The world's first bus service started this year from a shop in Nantes called 'Omnes Omnibus'

500 TONNES

The average cumulus cloud weighs about the same as 100 adult African elephants

© Getty

MOTORSPORT HAS ALREADY CHANGED THE WORLD.



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